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Electrical boring machine in an Anjou slate quarry

SLATE QUARRIES OF THE ANJOU, FRANCE. (See page 25)

Radiometallography*

Modern Science Lends Man Argus' Eyes to Study the Structure of Metals

Report of the General Discussion at Joint Meeting of the Röntgen and Farraday Societies

THE general discussion on the "Examination of Metals by X-rays," which took place at a joint meeting of the Röntgen and Faraday Societies in the rooms of the Royal Society on Tuesday last, gave evidence of the large amount of work that has been done in the development of this method of examining various ferrous, non-ferrous and other materials, but perhaps more important still, it demonstrated what an important part radiometallography will play in the future as an additional test of material.

As usual, a long series of papers had been arranged for, dealing with practically every phase of the subject. Sir Robert Hadfield, F.R.S., President of the Faraday Society, presided, and in his introductory remarks said he had suggested the holding of such a discussion because it seemed to him that in this method of examination there lay a great future for the detection of flaws and imperfections in various ferrous, non-ferrous, and other materials upon which the safety of human life often depends. Such an examination, if unfairly used, might give the manufacturer great trouble and expense, but we must never hesitate to consider, and if necessary adopt, means for improving general practice in the production of constructive materials. In saying this he had no wish to cast any doubt upon the modern production of metallic products, the great improvement in the manufacture of which had been wonderful, especially during the last decade. For instance, at one time during the war his own firm was turning out close upon 8,000 9.2 in. high-explosive shells weekly, and notwithstanding the hurry and rush of those terrible times, he had never heard of a single failure through defects. The same remark applied to some 6,000 guns and tubes for guns, howitzers, and trench mortars, which his firm supplied in about twenty months.

One of the troubles of the past had been that X-ray examination could only be applied to comparatively thin sections of metal. Some investigators had been able to deal with iron and steel sections up to 4 in. in thickness, and he believed that new apparatus had been completed and was now at work in this country with which it was hoped to be able to penetrate up to 9 in. thickness. Some time ago he had suggested to Professor W. H. Bragg that it would be most interesting to carry out X-ray examinations of various steels and ferrous alloys in order to ascertain whether their structure showed anything of a special nature. Professor Bragg having expressed his willingness to do so, a considerable number of specimens had been prepared, as well as specimens of various elements. The latter were as pure as it was possible to get them, although in some cases the purity fell short of the ideal. That was particularly the case with silicon. These specimens of iron, nickel and cobalt had been submitted in the hope that the study of their structure might lead to some explanation of the differences of their physical properties. It was well known that notwithstanding the fact that these metals were in the same group in the Periodic Table, their physical properties were quite different, while the heat changes or critical points showed considerable differences. The critical point in nickel was 350 deg. C.; in iron, 770 deg. C.; and in cobalt, 1,100 deg. C. By "critical point" was meant the temperature at which each of the metals changed from magnetic into non-magnetic condition. As regards iron, its change was not quite so sudden; there was a loss of magnetic susceptibility at 730 deg. C., which did not completely disappear until about 770 deg. C. was reached. A similar range might exist with regard to nickel and cobalt, but these two elements had not yet been so carefully examined. Another curious point was that, so far as was known, cobalt, alloyed with iron, does not give a non-magnetic material. In the case of manganese steel, upon adding manganese in sufficient quantities—say, 12 per cent. and upwards—notwithstanding the presence of some 88 per cent. of iron, the material became non-magnetic. In some way between 24 and 26 per cent. of nickel made iron non-magnetic, but no alloys yet made of iron and cobalt appeared to be non-magnetic, which was rather a curious point, except that, of course, the much higher critical point of cobalt no doubt decided this point. Sir Robert concluded his opening remarks with some interesting notes on some of the recent papers published in this country, America, France, Japan, and Germany on the subject of X-ray examination of ferrous products.

Professor Bragg then delivered a very interesting lecture on "The Elementary Principles of Radio-metallography," commencing with the production of X-rays from the target of the Coolidge tube. He explained that these rays differed from light waves only with respect to their shorter wave lengths. On this account the rays did not obey the ordinary laws of reflection and refraction, but could pass directly into any obstacle. Within the material of the obstacle the rays suffered absorption and actual penetration depended on the density and thickness of the material. A suitable object interposed between the rays and an ordinary photographic plate therefore resulted in a shadow photograph projected through its interior. Professor Bragg showed a number of slides on the screen illustrating his remarks. In every case the denser or thicker parts of the object appeared lighter in contrast with the remainder of the photograph; even the tool marks on the surface of a steel block were quite clearly defined, showing the extreme sensitiveness of the rays to a difference in thickness of the material. This was further illustrated by a remarkable photograph of some orange blossoms, in which the structural details of the delicate petals and leaves were plainly visible. Professor Bragg concluded his lecture by referring to the possibilities of X-ray spectrum analysis. A photograph of an X-ray spectrum was shown, in which two bands were clearly defined; it was explained that these lines were due to the absorption of X-rays by the silver and bromine of the photographic plate. All known elements have these X-ray absorption bands and their positions are much more regular and more simply related to the material than are the bands of the visible spectrum, and it would appear that the simplicity of the X-ray spectra, compared with the visible spectra, should render the former especially useful both for scientific investigation and as a means of chemical analysis.

Lieut.-Col. C. F. Jenkin, of the Air Board, said that considerable claims had recently been made for X-rays as detectors of hidden flaws in steel. The only flaws in which he was interested were the hair cracks, which gave considerable trouble in aero-engine crank shafts, and although there seemed to be no likelihood that X-rays could reveal them, he was persuaded to test the matter practically. Samples were therefore examined by experts who were pushing the process. They were pieces cut from crank shafts with large and relatively obvious flaws, but no trace of defects was shown by the X-rays. One sample about 2cm. thick was cracked right through the thickness for a length of about 6 cm., but there was no evidence of the crack in the radiograph. If such large flaws could not be detected it was obvious that the method was useless for finding hair cracks.

In a paper describing the researches into the X-ray examination of metals at the laboratories of Messrs. Schneider, le Creusot, Mr. E. Schneider said that since the apparatus was installed investigations had been carried out (*a*) into segregation and blow-holes and the influence of aluminum upon cast steel, (*b*) examination of steels containing different percentages of tungsten, and (*c*) the examination of compound steels. The general conclusions drawn from the work so far carried out were that in our present state of knowledge of X-rays and their production the application of radio-metallography enabled an examination to be made of ordinary steels provided their thickness did not exceed 40 mm. to 45 mm. This limiting thickness was reduced when the steel contained at least one constituent of higher atomic weight. It would be of inestimable value if ingots of 20 cm. could be radiographed, but unfortunately we had not yet reached that stage. Nevertheless, every step in the direction of finding a detector more sensitive to X-rays than those already known would lead to progress in radio-metallography. Similarly, as the means of producing X-rays of high penetrative power were improved it would be possible to increase the scope of X-rays in the examination of metals. An interesting application of radiography mentioned by Mr. Schneider was as an aid in sorting out mixed bars of metal, obviating the necessity for a chemical analysis. If, for instance, carbon steel bars had been mixed up with tungsten steel bars, they could be sorted out speedily. Bars of unknown composition and a bar of standard steel were placed on a slab. A radiograph was then taken and the opacity associated with each bar measured in that way. The values obtained compared against a chart drawn up from steels of known composition permitted of a deduction of the nature of the various bars.

Major G. W. C. Kaye gave an interesting account, and showed a number of striking radiographs of the application of radiography for the examination of timber for aircraft work both in the raw stage and as the finished product. Incidentally, he drew attention to the low efficiency of the apparatus now in use for dealing with steels. The efficiency of the X-ray tube, for instance, was of the order of one-tenth and 1 per cent. Again, about 90 per cent. of the high-potential energy for X-ray work was generated by induction coil, the efficiency of which was less than 50 or 60 per cent. A tremendous amount of work would have to be done to improve the apparatus. The slides which Major Kaye threw on the screen revealed many serious faults in workmanship in struts and other parts used for aircraft, and, but for X-ray examination, there is little dobut that there would have been many serious accidents, and almost certainly loss of life, and it is not surprising that in the inspection of timber X-ray examination as an adjunct to the stock of tests is regarded as essential. With the design of portable apparatus and a supply of alternating current available, Major Kaye looks forward to the time when for aircraft work, at any rate, inspectors will carry their apparatus about with them and make examinations on the spot.

A series of communications was presented by Sir Robert Hadfield, F.R.S., in conjunction with Mr. S. A. Main and Mr. J. Brooksbank. In a note on X-ray examination as applied to the metallurgy of steel, the application of this method of examination to welding is pointed to. As regards the expense of the apparatus for X-ray examination, this is heavy, and the apparatus costly and delicate, so that its operation is suited rather for an expert than for routine purposes. In the present state of the science, X-ray examination does not magnify defects, hence its utility is limited to those defects which are of a size within the visibility of the naked eye. Consequently, as many of the defects in steel arise from microscopic causes, we must still rely for their elucidation on the valuable work covered by micrography.

Another paper by the same authors described experiments carried out some time ago by the Hadfield Research Laboratory on the absorption power of different steels under the X-rays. These experiments have not been previously described, and, while much progress has since been made and the experiments in question were of a simple nature, they were put forward as interesting, illustrating as they did an early attempt to apply the method of X-ray examination to steel.

A third paper from the same source dealt with the radiographic examination of carbon electrodes used in electric steel-making furnaces. This investigation was carried out in view of the trouble experienced with electrodes in electric steel-making furnaces due to various causes, and it was thought radiographic examination might help to show internal causes accounting for their inconsistent behavior. These carbon electrodes are of two kinds, viz., those known as amorphous, and graphite electrodes. The former gives most trouble, and the data in the paper referred more particularly to this type of electrode. A number of electrodes from different makers were obtained, but the authors confessed that not much further light was thrown on the behavior of electrodes as the result of the work carried out, details of which are given. Probably the best use of radiographic examination might be made in connection with systematic experiments on electrode manufacture, where variations of composition, baking temperature, &c., could be carried out step by step. At the same time, the examination which was carried out on the manufactured electrodes was of considerable service to Messrs. Hadfield's and the information given in the paper should of be of interest to others engaged in the same line of work.

Captain Jackson, Admiralty Inspector of Steel in Sheffield, said that the inspector, generally speaking, could only examine the surface of material in the ordinary way, but the application of X-rays would now enable him to detect flaws which otherwise would have to be passed. Moreover, radiography enabled rapid examinations to be made, which were essential

*From *The Engineer* (London).

in dealing with large quantities of material. He looked forward to the time when the examination by X-rays would be more rapid than it was now, when it would be possible just to pass the material across some form of screen and see by the shadows whether there were any defects. One very important development which had not been reached was the examination of heavy forgings. One of the troubles with heavy gun forgings was the question of defects in the steel, and particularly with nickel-chrome. With this material there were typical flaws which did not appear on the surface. It happened that in turning a gun forging certain flaws were found. With further turning these disappeared, but other flaws appeared. When they came to the finished gun forging perhaps there were no visible flaws, and then the poor inspector had got to make up his mind whether there were any flaws in the forging or not. As he could not see them he had to say there were none. Consequently in order that no risks should be run it was necessary to have a large margin of safety in the design which it might be possible to reduce if they could be perfectly certain that there were no flaws. A large margin of safety meant that there was unnecessary strength, the article was heavier than it need be, and there was a waste of material and of efficiency. Consequently, if X-ray examination could be developed so as to ensure that thick steel forgings could be thoroughly examined it would be of great practical advantage in the development of ordnance. Another point where it would be of value was in connection with fuses. During such times of pressure as we had recently been through the assembly of fuses was carried out with great rapidity, as also was the examination, and there was the possibility of important components being omitted. In two particular cases which came under his notice it was desired to know whether the components might not have been omitted from certain fuses, and had this system of X-ray examination been available in the early stages it would have enabled him to make the examination without the necessity of having to take every fuse to pieces to see if the component was there. The work involved was enormous, and he was very grateful for the information which had been given him in the discussion.

Mr. S. A. Pollock, representing the Postmaster-General, said that the postoffice twenty years ago had appreciated the possibility of using X-rays for the examination of soft materials, as for instance, the examination of gutta-percha on submarine cables. It was the common practice for the packers of gutta-percha abroad to adulterate it in all forms, and it was very difficult to select samples which were absolutely pure. Therefore X-rays had been used for examining such materials. The postoffice had not yet used X-rays for examining steels; in fact, that was a new development. There were, however, quite a number of problems occupying the postoffice at the present time in metallography, and it had been used for discovering defects in the lead sheaths of underground cables which gave a great deal of trouble. It was sometimes found that within a few years of a lead-sheathed cable, costing perhaps £100,000, being put into the ground the sheath was defective in some way, and the cable had to be drawn out and replaced. Metallography had been found extremely useful in that way. It had on occasion enabled them to locate definite faults in manufacture. Then the postoffice was very much interested to know why stainless steel could be made to resist oxidation and to resist nitric and hydrochloric acids. They would like to know whether X-ray investigations would show the reasons for the non-corrodibility of that steel. Corrosion was of very great importance in the life of submarine cables, and he was looking forward to metallography affording very useful information in regard to the corrosion-resisting qualities of steel, and so enabling a definite estimate to be made of the life of steel used with submarine cables. He was very much interested in the examination of wood by X-rays, which, of course, was of great interest to the postoffice, which was a very big user of wood, particularly oak, for the arms of telephone and telegraph poles. It was sometimes a very difficult thing for a postoffice engineer to determine whether a telegraph pole had reached the point when it required renewal. A pole might be perfectly sound externally and yet be very unsound internally.

Papers of a high quality, but of more interest to physicists than to engineers, were also presented, dealing with the behavior of photographic plates, contrast and exposure in X-ray photographs through metals, and a method of testing an X-ray tube for definition. There was a comprehensive exhibition of X-ray photographs, and demonstrations with their apparatus were given by representatives of several manufacturers.

The Cast Steel Ship Development

POSSIBILITIES of developing a new resource for shipbuilding by using steel castings and welding labor was first brought to the attention of the Shipping Board in April, 1917, and was referred by the Shipping Board to the Emergency Fleet Corporation.

General Goethals expressed his readiness to undertake this development if the then naval architect, Theodore Ferris, would recommend it. The appropriation for ships was passed and Mr. Ferris recommended it in May, 1917. The appropriation was passed in June. At this time the Goethals-Denman situation arose and General Goethals was unable to take action. It was about this time that his connection with the Emergency Fleet Corporation was severed. Admirals Capps and Harris refused to give the matter a serious hearing, so that the development was thrown onto the shoulders of private interests.

A corporation was accordingly organized to develop a new system of shipbuilding, using cast steel sections, in this way employing labor resources and supplies of raw material, not then used in shipyards, for the purpose of helping win the war.

Chief of the difficulties encountered in the engineering work of developing cast steel ships was the necessity for perfecting foundry methods for producing the castings. This problem, after many experiments, has been solved and methods devised whereby the castings comprising the hull structure may be produced with a simple molding equipment and unskilled mold labor with intelligent supervision and at low cost.

OPERATING ADVANTAGES.

A careful investigation of cost, in fact, has led the projectors of the cast steel ship to the conclusion that hulls of ships can be produced at a saving of more than 50 per cent. of the cost of hulls of riveted ships built under equal conditions.

At the same time the cargo-carrying capacity of the cast steel ship exceeds that of the riveted ship by at least 4 per cent., owing to the joints being cast, which eliminates connection metal.

The low cost involves a corresponding reduction in fixed charges and returns to capital, and the increased cargo-carrying capacity increases earnings so that under equal conditions the cast steel ship can make a profit at a lower freight rate than other types.

In a 10,000-ton D. W. C. cast steel cargo ship of the Isherwood type the weight of steel was calculated to be about 2,000 tons net in the hull and superstructure. This provides a carrying capacity of between 5 and 6 tons of cargo per ton of steel in the hull. The saving in weight is due to the elimination of connection metal between the plates and frames and most of the overlapping metal of butts and laps. The cast steel ship having the frame work cast integrally with the plating has also a greater structural strength.

The extent of damage due to accident is reduced, which in turn reduces the cost of repairs. It may be noted that the cast steel ship may be repaired in any port of the world by riveting plates and frames into the damaged portion as in the ordinary riveted ship.

A further factor in reducing repairs is the reduced rate of corrosion of cast steel as compared with ship plates, the corrosion being about one-quarter as much under equal conditions.

METHOD OF CASTING.

The castings are made from scrap steel (shovel scrap will do) having not over 0.06 per cent. of phosphorus and sulphur melted in an electric furnace, from which air is excluded, producing a steel of about 0.25 per cent. carbon and a low oxygen content. The result is a tensile strength of 70,000 lb.; elastic limit of 38,000 lb., and an elongation of 28 per cent. in 2 in., which are higher than for rolled plate steel.

Our molds are permanent with thin sand surfaces renewed for each casting, and with such forms skilled molding labor is practically eliminated and the amount of man work per ton of castings is small, a casting approximately ½ in. thick and 10 ft. 6 in. long. As many units may be cast in one casting as may be desired, say, extending from the bilge to the rail of the ship. When two or more units are cast together there are as many pouring gates as there are units, the metal being poured down the channels in the mold forming the bulbs.

The molds are so inclined as to have somewhat the effect of bottom pouring, the top edges of the flowing metal being liquid until the mold is filled. This facilitates the free escape of gases from the metal and prevents the formation of gas pockets in castings. Dry sand molds prevent pitting. The character of sand used provides a smooth surface, the sand scaling off when the casting is rapped. Suitable chills are employed in fillets and over bulbs. Castings come out of the sand true and oil tight.

SYSTEM OF FRAMING AND PLATING.

This system of shipbuilding has been developed, employing flat castings, except for the castings of the bilge, which are treated in the annealing oven to give them suitable curves and warps.

By having the frames of the ship normal to the shell throughout, it is possible to cast the shell (except the bilge), the inner bottom, decks and bulkheads in one or two molds in which the thickness of the castings and depths of frames may be varied by scraping more or less off the surfaces of the sand rammed on permanent forms for each casting. The bilge castings require an extra curved mold for the forward and after body.

The sections are so designed that the ship may be built from either end or from a middle point. If a ship is started in the middle and built in both directions two gantry cranes spanning the hull may be employed, one hook on each crane for each side of the ship, four hooks in all; and each hook can land a casting in place well inside of 10 min. There are some 2,000 castings to be handled in a 10,000-ton ship.

The method of assembling is: To keel castings are secured bottom castings, each having longitudinals and half of a main transverse floor. Next intermediate floor castings are located. Tank top castings follow, each having longitudinals and the other half of a floor. Next are assembled bilge castings. Side castings are located, each carrying longitudinals and margin plates, the inner parts of main transverses. Then come hatchways supported on stanchions, followed by deck castings. Bulkhead castings and other details are located in proper order.

THE SPECIAL JOINT.

The joints between the castings are of particular interest and are made possible by the casting process. One edge is provided with lugs and the other edge with dovetails interlocked in place by electric arc welding. They fit loosely to allow for the go and come between the castings due to variations in contractions. The interlocking parts are so arranged and designed that the mechanical strength of the joint, due to the tensile strength of the dovetails and the resistance to shear of the lugs, is equal to the tensile strength of the plates. The seam upon the outside is also electrically welded to render the joint water tight, as is indicated in the drawing. The mechanical strength of this joint is 100 per cent. of the plating, a result long sought for in shipbuilding.

The welding upon the lugs and in the seam adds well over 200 per cent. to the strength of the joint provided the welding is sound. If it should be defective or part for any reason, the worst that could happen would be a leak through a slight crevice which may be temporarily remedied by calking inside of the hull.

FATIGUE OF WELDED JOINTS.

One of the defects of welding is its inability to withstand fatiguing strains due to the bending of the joint under variable stresses. This is remedied by a joint which is of such a heavy mass that bending strains cannot occur across the joint. The bending action occurs in the plates on either side of the joint. The bending strains along the joints are prevented by the frames or longitudinals along which they run. In fact all the joints of the shell, decks, etc., of the ship lie along the frames or longitudinals of the ship, so that bending strains can exert no fatigue stresses in the joints and the welding is never weakened.

Such joints are of the very greatest importance in welded ships. The welded joints heretofore proposed are subject to these fatiguing strains, and it is believed by the writer that in time serious damage and possible loss of the ship may result from the parting of a welded joint heretofore proposed, due to the fatigue of the metal under continued stresses. While a welded joint is shown in the photographs it is possible under the patent rights of the company to build riveted cast steel ships as well and either the transverse or longitudinal system of shipbuilding.

As the joints are superior in strength to the plates, butts no longer have to be shifted.

The castings are fastened together temporarily for welding by a system of wedging. When the castings are fitted to each other there are spaces under the ends of longitudinals within which to drive wedges to bring the edges of the casting tightly together. One or two men can tighten the edges of the castings as fast as assembled and faired up. After they have been wedged together, lugs at extreme ends of a casting are welded between their dovetails, and then intermediate lugs here and there are welded until all of the lugs have been welded into position between the

(*Concluded on p. 32*)

Dimetrodon Gigas

A Giant Spiny Lizard from Texas Bone Beds

By C. W. Gilmore, U. S. National Museum

Photographs by Courtesy of U. S. National Museum

THE section of Vertebrate Paleontology of the United States National Museum at Washington has recently completed the mounting for exhibition of a skeleton of the extinct Spined Reptile known in scientific circles by the name of *Dimetrodon gigas*.

No less than three specimens of a smaller species, (*Dimetrodon incisivus*) mounted in bas relief are displayed in as many museums of this country, but this is the first attempt to reconstruct a free mount of the entire skeleton, and the success of the undertaking may be best judged by an examination of the photographic reproduction of the specimen here shown. This new and imposing mount forms a noteworthy and important addition to the constantly growing collection of extinct animal life, which now fills one of the larger halls of the museum and to which a young lady visitor flippantly referred as the "dead circus."

The specimen was secured by purchase from the veteran collector of fossils, Mr. Charles H. Sternberg, who with his son Levi, in the spring of 1917 collected it together with many other specimens from a deposit of fossils known as the "Craddock Bone Bed," located on the Craddock ranch some six miles northwest of the town of Seymour, Baylor County, Texas. The deposit covered a space of several hundred square feet, the bones extending through a thickness of about one foot, and usually in the most perfect preservation. These consist of scattered parts pertaining chiefly to the genus Dimetrodon, with an occasional partially articulated skeleton as the present one of *Dimetrodon gigas*. In the collection made there are several hundred separate skulls, jaws, limbs and other bones of the many curious animals that inhabited this region in those ancient days. All are now in the collection of the U. S. National Museum.

The difficult mechanical problems embodied in the mounting of a skeleton of such fragile nature, made still more arduous by the constant striving to have the supporting iron work as inconspicuous as possible, is a piece of modern engineering successfully accomplished by Mr. T. J. Horne, Preparator in the Section of Vertebrate Paleontology.

An idea of the painstaking care required in fitting together the broken pieces of bone, cleaning off the adhering matrix, restoring missing portions and articulating and mounting the bones of this skeleton, may be gleaned from the fact that eighteen months of steady labor of one man was bestowed upon this specimen from the time it was received at the museum until ready for exhibition to the public. Much time was in addition devoted by the writer to critical study in working out some of the more difficult problems in connection with the proper pose and articulation of the bones. The pose adopted is one suggested by a careful study of living lizards and is an attitude often assumed by those land forms of the present day when slightly irritated, that is, with the front of the body raised slightly from the ground, the rear portion lowered, with hind limbs spread out, head raised with jaws open showing the rows of strong bristling teeth, thus giving the animal an appearance of angrily defying one who has suddenly blocked his path.

The most striking and extraordinary feature of *Dimetrodon* is the high dorsal fin along the median line of the back formed by the elongation of the neutral spines of the vertebrae. These range in length from 6 inches on the neck to over 3½ feet above the center of the back, where they reach their maximum development, becoming successively shorter as the tail is approached. That in life these tall spinous processes were united by a thin membrane of scaled skin there is little doubt. The foreign savants, Professors Abel and Jaekal, are disposed to think the spines were covered by skin, but not connected, but this seems to be highly improbable.

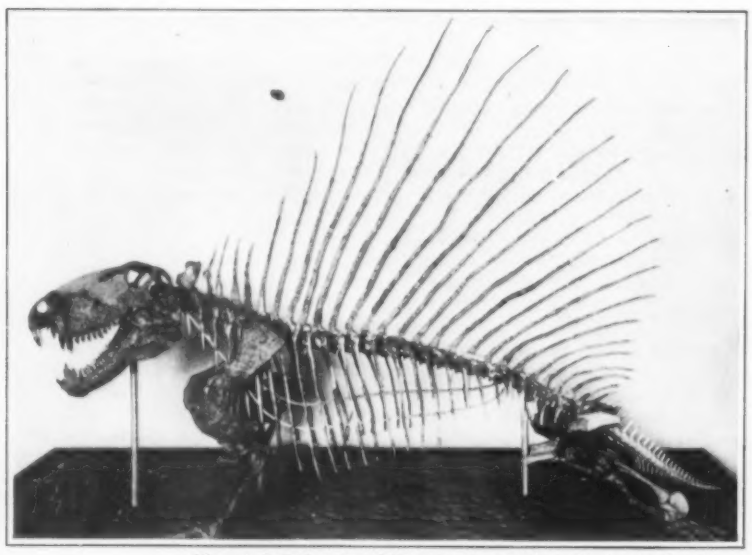
The living Central American lizard Basiliscus Plumifrons. A remote relative of the Dimetrodon and the best suggestion of the latter's appearance

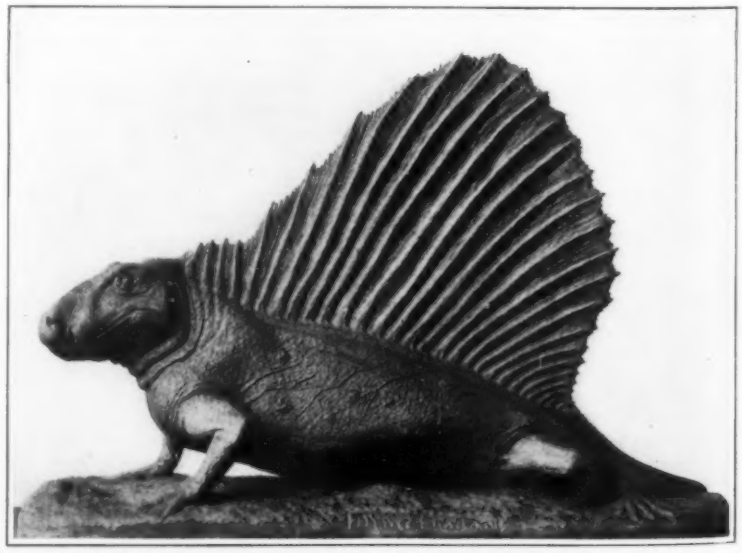
The one living lizard which appears to throw some light on the solution of this problem, and which is very remotely related to *Dimetrodon*, is *Basiliscus plumifrons*, from Tropical America. The crest on the back as shown in the illustration, though not so high or extensive as in *Dimetrodon*, is nevertheless supported by the elongated spinous processes of the vertebrae and these bear a striking resemblance to the crest of the extinct form. In general appearance all of the basilisks, of which there are several species, suggests the idea of lizards upon whose backs has been grafted a fish's fin and it seems that in this animal we have the best suggestion of the probable appearance in life of the *Dimetrodon* fin or crest along the back.

In trying to account for some practical use for this unusual appendage it has been suggested that it may have resembled some of the ancient vegetation and thus served to conceal the animal as it lay in wait for its prey, or for better concealment from its enemies. Professor Case, the acknowledged authority on the Permian reptiles, says of these, "The elongate spines were useless so far as I can imagine, and I have been puzzling over them for several years. It is impossible to conceive of them as useful either for defense or concealment, or in any other way than as a great burden to the creatures that bore them. They must have been a nuisance in getting through the vegetation and a great drain upon the creature's vitality, both to develop them and to keep them in repair. The genus succeeded despite of them, or perished because of them." The handicap which *Dimetrodon* would labor under in a high wind is strikingly illustrated by Dr. Alexander Ruthven's observation on a large specimen of *Basiliscus*, noted upon the banks of the Magdelena River in the United States of Colombia. "This individual ran out upon a rock in the river in pursuit of an insect and there encountered a strong breeze blowing upon the side of the dorsal fin. Under the pressure of the wind the animal was thrown well over to one side and seemed to have considerable difficulty in maintaining its position." Such an effect would have been decidedly increased upon Dimetrodon with a fin proportionately of much greater area.

It is also of interest to know that among the fishes we have in the Sail-fish (*Istiophorus nigricans*) a high dorsal fin, which though totally different in structure from Dimetrodon shows a decided similarity in the external form, and its great relative size. This enlarged fin extends nearly the whole length of the back and reaches a great height as here shown. Günther in his "Study of Fishes" says: "It is stated that the Sword fish (*Istiophorus*) when quietly floating with the dorsal fin erect can sail before the wind like a boat." It may be that knowledge of this habit in the living sail fish is what led Professor Cope years ago to suggest an acquatic habitat for Dimetrodon and its relative *Edaphosaurus*, a conclusion entirely at variance with present day conceptions.

The head of *Dimetrodon* is enormously large in proportion to the size of the body. The jaws are provided with powerful incisor and maxillary tusks, the largest of which reach a length of three inches. The cheek teeth are recurved, with sharp, serate edges. There is no animal known which has a more efficient apparatus for the capture of its prey. The eyes were large and set well back and high in the head. The neck is short, the limbs are strong, having feet with five digits, each of which is terminated by a sharp claw. No specimen has as yet been found with a complete tail, but the rapid decrease in size of the





Mounted skeleton and life-size restoration of Dimetrodon gigas, whose great backfin was a hindrance and danger in brisk breezes

known caudal vertebrae suggests a short tail and it has been so restored in the mounted skeleton. The specimen here pictured is about seven feet in length and over five feet in height, and while this is the largest species of the genus there were individuals that attained a considerably larger size. The presence of the greater number of the ribs of both sides shows the great depth of the body cavity, and the extreme flatness of the sides of the anterior part of the body, and from a study of the habits of living reptiles it is known that those with compressed bodies are usually dwellers among bushes and trees. Professor Case is of the opinion that Dimetrodon is descended from an acquatic ancestry, and that it ranged widely over the land. It is probable that ordinarily the animal did not raise his body far above the ground, but crawled around much after the fashion of the crocodile, though quoting again from the above author, "the strong limbs with longer foreleg than upper leg, with strong feet, appears to be ample evidence of an ability to run with some speed and perhaps even leap or pounce upon prey. Abel in his 'Paleobiologie,' points out that running and leaping animals have the foreleg longer than the upper leg and creeping animals have the proportions reversed. It is not probable that Dimetrodon was ever capable of leaping any distance, but it certainly was able to move swiftly for a short space. Probably it lay hidden in the vegetation and made short, scuttling rushes upon its prey, ending possibly, with a short pounce which permitted its weight to add something to the vigor of attack by tooth and claw."

Dimetrodon was the dominant and probably the most formidable animal of his time. Of the contemporary animals of the Permian there was a vast assemblage of reptiles and amphibians and it was these that the cruel jaws were peculiarly adapted for catching. The borders of pools and swampy places were probably the regions most densely populated by these lesser forms and no doubt such places were the favorite haunts of the Dimetrodon around dinner time.

The writer has prepared a model restoration one-sixth natural size of Dimetrodon based on the mounted skeleton, which depicts his conception of the probable appearance of this creature in the flesh.

New Observations Concerning the "Terrifying Positions" in Animals

CERTAIN animals when startled by the approach of enemies, real or supposed, instantly assume an extraordinary and apparently menacing position, which is sometimes called *the terrifying position* and sometimes the *position of combat*. Familiar examples of this are the swollen and erected tail of a cat when frightened and the inflated neck and erected head of the cobra. Some naturalists have believed this action on the part of the animal to be *conscious*, i. e. regulated to a certain extent by the will of the animal.

The object of the attitude is supposedly protection. Weismann, for example, came to the conclusion that rapacious animals are afraid to approach their prey when they perceive the terrifying position, basing his views upon observation of the caterpillars of the *Chaerocampa elpenor*. Recent observations made in the zoological laboratory of the Botanical Gardens at Buitenzorg in Java, by Mr. Michel Siedlecki, have led him to believe that this view is not entirely correct. He has made a report of his study of the subject in the *Comptes Rendus* of the Société de Biologie of France which we find worth quoting:

"The first thing to be noted is that in many cases, such for example as that of the great spiders (*Selenocosmia javinica*) or the scorpions (*Heterometrus javanicus*), the animals when assuming the terrifying position exhibit their means of defence (i. e. stings or the poisonous dart) and place them in a position to facilitate the actual attack; but there are others, on the contrary, which behave very differently.

"The cobra does not inflate its neck and lift its head when striking its prey. The beautiful brown mantis (*Deroplatys desiccata*) when catching sight of a lizard spreads its wings, upon which brilliant blue spots appear, and lifts its large anterior legs; but when it approaches to capture its prey its wings remain closed and its pincers are folded beneath the thorax. The European mantis when engaged in combat with one of its fellows often fails to take the terrifying position, according to Fabre.

"The terrifying position is very often quite without value as a means of defence. I have observed a large lizard (*Gecko verticillatus*) which exhibited no hesitation in devouring a mantis in the said position. I have also seen a mantis catch a caterpillar of the *Papilio demolion* holding itself in a position closely resembling that of the caterpillar of the *Chaerocamp elpenor* studied by Weismann.

"It often occurs that the so-called terrifying attitude is produced when the animal is in no danger. I have seen a mantis (*Mantis laticollis*) take this position as soon as the cage in which it was enclosed was slightly shaken. On the other hand a mantis placed together with a scorpion in a large vessel vainly attempted to defend itself with its powerful fore legs, but did not assume the so-called position of combat.

"One of the most interesting things with regard to this matter is that the state in which the animal takes the terrifying position appears to be directly connected with the degree of fatigue affecting the animal. I first remarked this relation between fatigue and the terrifying position in a large lizard (*Varanus salvator*), 4½ feet (1.4 meters) in length, which had been brought to me in a basket by a Malay coolie. The animal was already quite weak and made no resistance when I placed it in a basin. It remained without food for three days, not stirring from its place even when touched with a stick. It was taken from the basin in order to be chloroformed, but at the moment when the laboratory assistant was placing its head in the sack for this purpose, the animal suddenly assumed a terrifying position. The fore legs were lifted, the throat was inflated, and the mouth was opened exhibiting its rows of teeth, while the tail became rigid and was lifted ready to strike in a truly impressive posture. But at this very moment the animal was so weakened that the man had no difficulty in escaping it."

The same animals which do not assume the terrifying attitude in a state of full vigor instantly make use of it when they are enfeebled. I have observed the females of the great yellow spiders (*Platythomisus octomaculatus*) lying upon their cocoons after depositing their eggs and building the cocoon; the instant they were approached the terrifying position was assumed. Supporting itself firmly upon the cocoon with the four posterior legs the animal extended its anterior extremities giving them a vibratory movement, so rapid as to be almost invisible. The spider somewhat resembled an enormous wasp, but far from being dangerous it was completely enfeebled and impotent. Before laying their eggs these females do not assume the terrifying posture. This grotesque position is not manifested until after the deposit of the eggs, when the organism is enfeebled by reason of the immense expenditure of substance. Furthermore, in certain cases I succeeded in occasioning the appearance of the terrifying posture by fatiguing the animals.

A mantis (*Mantis laticollis*) when frightened has the habit of extending its wings and its anterior extremities and then, while resting upon its four posterior legs, inflating the abdomen from which there protrude at this moment two pairs of small sacs placed between the two penultimate abdominal rings. These sacks are extremely vivid in color, the anterior pair being deep blue, the posterior pair red. It is not always easy to force the animal to take this extremely grotesque posture; I succeeded by shaking the animal, by dragging it by one leg and by approaching it suddenly with my hand when it was resting on a branch. The position lasts only thirty seconds and seems to require a great effort. I succeeded in fatiguing the animal by forcing it to run around its cage until it was so weak that it could no longer remain standing and it was then that it assumed a terrifying position; it inflated the abdomen and then succumbed without changing its position.

Identical facts have been observed in the flying lizards (*Draco volans* and *Draco fimbriatus*). These animals when chased attempt to flee on foot; when forced to leap they extend their parachute membranes and volplane for a long distance. But finally when excessively fatigued they are no longer able to run and they then assume the terrifying position, erecting themselves, opening the mouth, and extending the lateral membranes. If they are still urged to run or to leap they die of fatigue while still retaining the terrifying postures.

From these and other observations I have been led to form the following conclusion: In the majority of cases the terrifying posture is nothing more than a reflex action occasioned by a general irritation of the entire organism. It even occurs in many cases that this irritation is caused by a sensation obtained through the senses; in such cases the posture has every appearance of being voluntary, but the same effect can be obtained by other actions such as fatigue, which involves the whole organism; hence we cannot think it voluntary or conscious.

The Influence of the Wind Upon the Distribution of Glaciers

DURING the course of an extensive study of the region of lofty mountains in the northern part of the Scandinavian peninsula, Mr. Enquist was struck by the fact that glaciers and fields of perennial snow were massed in an extraordinarily pronounced manner upon the eastern slope of the mountains. Moreover, if the orientation of the glaciers be represented upon a map by arrows, it will be found that their directions bear a close relation to the lines upon a mariner's chart, a fact which instantly indicates the influence exerted by the prevailing winds. Mr. Enquist formulated the following law:

Glaciers and fields of perennial snow are formed principally upon the side of mountains lying in the path of the prevailing snow-bearing winds.

It will be seen at once that this regular relation between the orientation of glaciers and the direction of the wind is capable of being made use of in researches with respect to meteorology and to climate. It is obvious, for example, that maps showing the distribution of glaciers in a given area would clearly indicate the direction of the prevailing winter winds in the said area. This fact is of great importance since topographical maps showing the distribution of glaciers are comparatively easy to make during the warm months, while on the other hand direct observations of the wind in high mountain areas can only be made, especially in the winter, with enormous difficulty; direct observations in mountain regions such as the Andes and the Himalayas, or in the vicinity of the poles are practically impossible most of the time. Even when such observations are recorded, they are apt to indicate winds which are merely local, especially when made in valleys; and such local winds being due to the character of the surrounding topography may differ notably from the unhampered winds of the peaks. And in regions such as commonly occur in the tropics where different systems of winds blow at different elevations above the level of the sea, observations taken at one season may be without value with respect to another.

This method of determining the direction of the prevailing winds may prove peculiarly important in physical geography in the study of the glacial epoch. Thus by the examination of the traces left by the glaciers of this period and above all of the orientation of the moraines, etc., it may be possible to make a direct determination of the winds which prevailed at that time in the various parts of the earth. By comparing these data with present conditions, certain conclusions can be arrived at regarding the climate of the glacial epoch. And just here we have a great advantage: namely, that during this epoch there were glaciers in many regions where they no longer exist, so that we thus possess a series of observations more extensive and more closely knit than for our own time.

Mr. Enquist has arrived at the following conclusions with respect to the distribution of pressures, during the period of maximum glaciation:

A strongly marked higher pressure must have existed upon the great ice fields of the Northern Hemisphere, due to the cooling influence of the ice. The region of low pressures which exists at the present time in the northern part of the Atlantic area—the Icelandic Low—consequently did not then exist. In place of this [he believes] there was a domain of strongly marked low pressures formed over the southern part of the North Atlantic, just where we have today the Azores High. Its northern limit was found approximately adjacent to the southern limit of the present minimum of Iceland. This minimum appears to have extended westward over a portion of North America. The present maximum of the Azores—probably diminished—was displaced towards the south over the tropics.

The minimum which occurs at the present time during the winter over the northern portion of the Pacific Ocean was much more pronounced. It extended—just contrary to present conditions—over the southern portion of the Rocky Mountains, where it encountered the minimum of the Atlantic. To the south of this minimum a maximum was doubtless formed.

The two minima mentioned above, which compensated the regions of maxima in the north, must likewise have remained throughout the year. Both must have been equally well marked, especially in winter by analogy with present conditions; because of the high gradients of these maxima and minima of the glacial age, the winds in the limited regions which divided them must have taken on the character of tempests and this must have exerted a powerful influence upon the orientation of snow deposits.

As to other portions of the earth there is no reason to suppose that there was any marked modification of the present distribution of pressures. Hence the glaciers of the Ice Age so far as we can trace them, indicate the same prevailing directions of the wind as do the glaciers of the present time.—F. E. ENQUIST in *Bull. Geol. Instit. Upsala.*

Honey*

Newest Theories Concerning the Function of the Nectary in Flowers

By Gaston Bonnier, Member of the French Academy of Sciences

WHILE most people are familiar with honey and it has been used and enjoyed by man for untold ages, comparatively few are acquainted with recent theories concerning the origin and nature of this product of the bees or of the nature and function of the nectar in plants which is its raw material. In a recent issue of the *Revue Hebdomadaire* the distinguished botanist and plant physiologist, M. Gaston Bonnier, of the French Academy of Sciences discusses the subject exhaustively though in a popular vein. The article is too long for reproduction here but we extract from it some of the most interesting portions.

It is a common mistake to think that the wax of which honeycombs are composed is composed of substances gathered by the bees and later fashioned into the desired shape. This is quite untrue. The wax being, in fact, a secretion formed within the tissues of the insect. This fatty body is formed in special glands which are situated underneath several rings of the abdomen, whence the wax exudes in the form of small whitish lamellæ, which the bees gather with their legs and transport to their mouths to make small balls which serve as material when they are constructing the combs, which are white at first, but become yellowish under the influence of the transpiration of the insects. It is a common mistake to suppose that pollen is the raw material of the wax, but pollen is a nitrogenous body and wax does not contain nitrogenous matter.

A grain of pollen is an organized cell containing living substance, sugars and starch; each grain of pollen is surrounded by cellulose and contains a great many other substances of various sorts. Wax, on the contrary, is a non-organized, inert, uniform, fatty substance of a composition which is always identical, hence it is materially impossible that honeycombs should be built of agglutinated pollen. The celebrated chemist, J. B. Dumas, and the great naturalist, Henry Milne Edwards, collaborated upon an experiment which is decisive in this respect. They isolated a group of bees from the external world during the time they were making their comb. Though they had only honey without pollen at their disposal, the insects continued to build by means of the small waxen scales produced from their glands, each bee requiring the consumption of more than 10 grams of honey in order to secrete one gram of wax. . . .

Only a very small part of the nectar transformed into honey is used in feeding the adult bees. A very considerable part of the honey is used in making a sort of "broth," i. e. a mixture of pollen, honey and water which is employed in nourishing the larvæ which issue from the eggs laid by the queen bee. But all of this constitutes only a very small part of the honey stored up in the hive.

In spite of the common idea bees do not sleep through the winter, but we can best explain the utility of this enormous provision of honey, of which the inhabitants of a hive sometimes use more than 10 kilograms during the winter season, by recalling the fact that the center of the group of bees within its hive is always at the same temperature, i. e. at exactly 33° C., and that this temperature is necessary for the development and "hatching" of the bee "brood," i. e. the assembled mass of eggs and larvæ. It is obviously necessary, therefore, that the bees should liberate constantly an amount of heat sufficient to maintain the said temperature. They accomplish this by the combustion through respiration of the honey which they consume and they naturally consume very variable amounts for this reason—very little in the summer, when the external temperature is 25° C. for example, and enormous amounts during severe cold spells in winter. During periods of extreme heat in the summer, when the outside temperature is greater than 33° C., the bees usually come outside the hive and hang in clusters upon the hive or some nearby object, especially when the hives are exposed to direct sunlight. . . . Even in tropical countries bee colonies are usually found at such altitudes as imply a temperate climate. Certain species of bees, different from our own, are capable of living in a much warmer, though not really tropical climate, but among these the temperature of the colony is a little bit higher than 33° C., and furthermore, the wild hives are built in cool and shady places or else in crevices of the ground sufficiently deep to secure a lower temperature than the surface exposed to direct sunlight.

From the time of Aristotle and Theophrastus to that of Malpighi and Tournifort numerous authors have spoken of the production of honey from flowers, but in a very incidental or superficial manner. It was the French naturalist, Vaillant, who first treated this subject methodically in his work "Discourse Upon the Structure of Flowers." Vaillant called the parts of the flower, which produce a sugary substance, the *mielliers*, or honey-bearers. In 1735, Linnæus, who had recognized, without chemical analysis but by a sort if intuition, the fact that this sugary substance is not identical with honey, though it serves to produce it, borrowed from Theophrastus the word "nectar" and gave the name of "nectaries" to those portions of the flower whence this nectar exudes. . . . This study of the nectaries has been the subject of passionate discussions, of bitter criticisms and even of unqualified insults since the time of Linnæus, and is so still. Boehner in 1758, and Medicus in 1763 violently accused Linnæus of having given the same name of nectaries to organs very different in nature from each other; their contemporary Adamson joined in the attack and finally placed the nectaries among the number of those paradoxes which interrupt the progress of science. Numerous discussions arose, later, concerning the question as to which of the flower organs are to be regarded as related to the tissues producing nectar. Some authorities thought the calyx was concerned, others the corolla, and still others the stamens or the ovary. Some savants, on the contrary, regarded the nectaries as being independent of all these portions of the flower. Even the mathematician, Bravais, occupied himself with the question and believing he had solved the question, maintained that in reality the nectaries are not special organs but that an accumulation of sugar occurs at the base of flowers and even at that of leaves. This reasonable and just view met with no success at the time.

Another controversy arose with regard to the rôle of the nectaries and the function to be accomplished by the production of sugar in the flower. While some authorities maintained with Bravais that this provision of sweet substances, placed usually at the base of the flower, was of service in the future development of the fruit and the seeds, others pretended that the plant took this method of rejecting the sugar for which it had no use. But it must be noted that these various opinions, together with several others relating to the nectaries, were based on the very simple idea that the significance of the nectaries is directly related to the plant which bears them. During the period from 1789 to 1793, a great revolution occurred with regard to the rôle attributed to the nectaries.

A German, gifted with astonishing patience and with an imagination still more extraordinary, Pastor Christian Conrad Sprengel, had devoted himself to the examination of more than six hundred species of plants and to the study of the bees which came to visit their flowers. At great expense and trouble, being obliged to give private lessons to obtain the money required for publication, this author finally brought out his great work with the pretentious title "The Mystery of Nature Unveiled." According to Sprengel the key of the aforesaid mystery is the reciprocal adaptation of flowers and melliferous insects. According to this view the plant does not produce the nectaries for its own uses but with the object of furnishing an agreeable food to insects. However, the plant is paid for its sugary liquid by the work done by the bee for its benefit. That is, in visiting the flower to get the nectar the bee touches the stamens with some one of the fuzzy parts of its body, thus carrying away some of the pollen which is later transported inevitably and in an absolutely definite manner to the pistil of another flower of the same plant, so that by means of the cross-pollenation unconsciously accomplished by the bee, the plant produces better seeds than if the pollen of a flower were deposited upon a pistil of the same flower. In this exchange of good services Sprengel saw the primary cause of the form, the color, and the odor of flowers, and even the explanation of the slightest peculiarities of each species—the hairs, the stripes, the spots they might exhibit, etc. In short everything was explained!

Sprengel's work met with no success; and many naturalists, including the French botanist, Desvaux, pointed out instances in which it was inexact, since the author had allowed himself to distort his facts in his enthusiasm for his theory. But curiously enough, more than half a century later this infantile romance of Sprengel seduced the illustrious Darwin and following him all the German savants. Not only did each phrase in Sprengel's strange work become for them words of gospel truth, but his conclusions were even amplified, and the production of nectaries designed solely for the use of insects became a classic theory in instruction.

Those few persons who had the temerity to raise objections to this view or to institute experiments proving the falsity of this seductive theory, were vilified. Floods of ink began to flow on the subject of nectaries. I, myself, in fact, received most of this abuse. For the moment I content myself with quoting the following phrases from our great physiologist, Claude Bernard, by way of answer to Sprengel's fantastic hypothesis. Bernard declared that "the beet is quite without intention of sweetening the coffee of mankind when it manufactures sugar in its root," adding that "the sugar formed in the tissues of the beet is not designed to maintain the respiratory combustion of the animals which feed upon it; it is designed to be consumed by the beet itself during the second year of its vegetation. The law of physiological finality resides within each individual and not outside its organism; the living organism is made for itself and has its own intrinsic laws. It works for itself and not for other organisms."

Let us now inquire into the rôle played by this accumulation of sweet substances which is found at the base of all flowers, and what functions the nectaries may fulfil for the benefit of the plant itself.

It must not be forgotten that these tissues which are particularly rich in sugars exist in the flowers which do not produce nectar as well as in those which exude this substance. There is always found a large proportion of saccharose, i. e. of the sugar identical with that produced by the beet and the cane, and there is also found a variable proportion of glucose, or "fruit sugar," i. e. of a sugar which is identical with that which forms a white powder upon the surface of plums and other fleshy fruits of similar nature.

Let us consider Solomon's Seal. In the spring this plant, which is not unlike the Lilly of the Valley, produces a leaf-bearing stalk which also bears small groups of white flowers flecked with green, of elongated bell shape. But if we analyze the tissues at the base of the very young flower buds, i. e. those not more than three millimeters in length, we shall find that they contain 12 per cent. of cane sugar; when the buds are four times as great we shall find 25 per cent. of the same sugar, while at the base of the full blown flower, in the nectariferous tissues, we shall find 55 per cent. Note these figures: they show a constantly growing store of sugar which accumulates at the base of the flower until it is full blown. But now the flower stops growing and no longer increases in size. It is no longer a bud and it has not yet become a withered flower transforming itself into the fruit enclosing the seeds. Thus a flower completely opened is arrested in development and this is the moment when the greatest amount of sugar is stored up in the tissues of its nectaries. What is it waiting for in order to continue its development and become transformed into a fruit? The reason is that the further development has ceased to depend upon the flower itself; it cannot transform itself into fruit until the pollen of the stamens arrives upon the upper part of the pistil. But the necessary transportation of the pollen depends upon external circumstances, upon meteorological conditions and the resultant opening of the anther. If the weather is rainy or very humid the pollenization cannot occur and in this case the flower remains sterile and withers and falls; in the opposite case the flower becomes fertile as soon as the pollen has germinated upon the pistil. Evolution recommences, the corolla and the stamen wither away and the pistil and the ovules which it contains become considerably larger, the latter becoming the seeds enclosed in the fruit.

If we return now to our Solomon's Seal and wait till it is fertilized, which takes place in July, these facts are exhibited in a very simple manner. Suppose, for example, that at the moment of flowering the plant contained thirty-seven blossoms; then if we count the fruits in July and find only twenty-eight, this means

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *La Revue Hebdomadaire* (Paris).

that nine blosoms were not pollenized and therefore remain sterile, while twenty-eight received pollen upon the stigma of the pistil and were transformed into fruit. Let us now examine the nectriferous tissues at the base of the young fruit. The open flower, it will be remembered, contained 55 per cent. of cane sugar at its base, during its static period; eight days after pollenization only 38 per cent. is found; when the young fruit is twice as large as was the ovary of the flower, these tissues contain only 10 per cent. of sugar; and, finally, only 3 per cent. is found at the base of the fully grown fruit. These figures plainly show that the provision of sugar accumulated at the base of the flower gradually disappeared and other analyses of more complicated nature prove that the sugar in question has passed into the young fruit and the young seeds to assist in their first development. In other words, the young fruit has been nourished at the expense of the reserves of sugar in the nectaries.

Apropos of this let us quote Claude Bernard once more: "All living creatures are nourished in the same manner—neither plant nor animal is fed by a process of direct nutrition. The physiologic study of the phenomena in question proves that *nutrition is indirect.* The aliment disappears at first so far as concerns its definite chemical nature and it is not until later after a long continued organic process, after a complex vital elaboration, that the aliment arrives at the point of constituting the *reserves,* which are always identical and which serve to nourish the organism. In a word, the body is never nourished directly from the varied aliments ingested but always by the aid of *identical reserves which are prepared by a sort of process of secretion.* And what is here stated concerning the formation of nutritive reserves holds true in the animal as well as in the plant kingdom."

To vary the expression, when one eats a chop it is not the chop which nourishes us directly, for the alimentary substances which it contains are stored up in the reserves of fat in the adipose tissues or else in the reserves of nitrogeneous substances; that which nourishes us at the moment is material taken from the reserves of the body and may proceed from another chop which was ingested a week before.

When the young fruit which succeeds the flower begins to develop it is not nourished by the substances which are directly entering the plant at the moment, by means of assimilation in the green leaves or by the incorporation of the substances drawn from the soil by the roots; the young fruit is directly nourished by materials drawn from the reserves (including sugar) which are stored up in advance near the base of the flower.

Such appears to be the principal rôle of the nectaries—a rôle which is useful to the plant itself.

But what then is the significance of the actual nectar, i. e. of the sweet liquid produced upon the surface of the nectaries? And if all flowers have a reserve of sugar at the base, how does it happen that some of them yield nectar while others do not?

To answer these questions it must be recalled that a current of water is in constant circulation through the plant. The water absorbed by the roots rises in the capillary vessels and flows through the roots, stalks, leaves and blossoms, impregnating all the tissues and evaporating upon the entire surface of the plant in the form of water vapor; this is the transpiration of the plant. The Abbé Mariotte first proved this in the eighteenth century by covering with a bell glass any plant having its roots in damp earth; the inner wall of the bell glass is promptly covered with droplets of water proceeding from the condensation of the water vapor produced by the transpiration of the plant. But what becomes of this perpetual current of water traversing the plant when the air is saturated?

Under such conditions one may see in the early morning along the edge of the leaves of cabbages, poppies, etc., or at the point of the blades of wheat or oats delicate droplets which consist of water which is almost absolutely pure, as was proved by Berthelot. These limpid droplets are not formed by the dew, which when it is produced is deposited on all sorts of objects and on any portion whatever of plants, since it consists merely of the condensation of the water vapor present in the air. But if we take pains to examine during a dewless night the serrated edges of the leaves mentioned above, we shall see these delicate droplets issue from the plant and form "beads" along these portions of the edges of leaves, proving that they come from the interior of the plant and not from the surrounding air. These minute beads of water are produced, in fact, by "arrested transpiration."

Put some pure water in a saucer and some very sweet water in another saucer and leave both exposed to the air. At the end of a certain length of time all of the pure water will have passed into the state of vapor, while the second saucer will still contain most of the sweetened water; sweetened water, therefore, evaporates much less readily than pure water. What happens then when the current of water circulates through the plant, pasing through the sugar holding tissues of the nectaries, when the latter are quite near the surface exposed to the air in the flower? There will be an arrest of transpiration at this point and the droplets of sweetened water which are formed in the flower, the water being urged by the pressure in the roots, will remain in the liquid state precisely because the water is sweet.

If we examine the structure of flowers which do not produce nectar we perceive that the tissues in which they accumulate sugar dot not form, as in nectar-bearing flowers, those swellings at the surface whose nature was so hotly discussed by the old naturalists. The reserve of sugar required for the early development of the fruit and seeds is situated more deeply; and except in unusual meteorological conditions the water which traverses them in passing through the unsweetened tissues that separate them from the external air arrives at the surface almost completely deprived of sugar, and transpires in the form of water vapor just as in the leaves or other parts of the flower. But these flowers which ordinarily produce no nectar may be forced to do so by placing the roots in a very humid soil and the stalk and flowers in air already saturated with water vapor. Tulips, for example, ordinarily produce no nectar, but if the roots of a flowering plant be immersed in water and the plant covered with a large bell glass, drops of sweet nectar promptly appear in each flower; a single blossom may be thus made to yield more than ten cubic millimeters of nectar. In short, nectar is the result of an arrested transpiration at the surface of those parts of the flower where a large quantity of sugar is accumulated. It may be termed a sort of "perspiration," in fact, except that it is sweet instead of salty like the "sweat of the brow" of mankind.

It is this liquid which is drawn up by the bee with the trumpet-shaped tongue, which it can extrude at will from the lower part of its mouth. Two prolongations at the right and left of the tongue end in a cluster of very fine "hairs" which are extremely sensitive; these prolongations are called the labial palpæ. Guided by these tactile organs the bee thrusts its tongue into the sweet liquid. This fine long tongue consists of a sort of hinged gutter which can be instantly transformed into a tube when the bee folds its two portions together. The nectar swallowed by this instrument, which is alternately extended and retracted, does not pass into the stomach; it is stored in an expanded portion of the œsophagus which forms a large pocket. A special muscle prevents this from emptying into the stomach. The bee collects only one kind of honey during a flight and the same bee which is sent out to gather nectar does not gather pollen at the same time. The principle of division of labor is strictly applied by the general staff of the hive, which knows that "time is money."

The nectar undergoes a partial chemical transformation while in pocket, whose walls produce a special substance called invertase which acts like a ferment, i. e., a very small quantity of this substance is capable of changing the saccharose or cane sugar into two different glucoses whose mixture forms "fruit sugar." When the bee disgorges the nectar into the cells of the comb it discharges a little invertase at the same time and the transformation of the sugar which began in the bag continues in the cell.

Furthermore, the cells are not filled to the top but only half-way or even less, so that the sweet liquid is spread over a large extent of comb. This enables the excess of water to be more readily evaporated, which is necessary since honey will not "keep" if it contains more than 25 per cent. of water, while nectar contains about 75 per cent.

If we examine the platform in front of the hive near the entrance, on a day when nectar is abundant, we shall observe rows of bees standing one behind the other, with head turned toward the hive, the abdomen lifted and engaged in so rapid a beating of the wings that the latter are actually invisible. The bees are all beating the air in the same direction in order to cause a current of air to enter the hive, to assist in the evaporation of the excess water. . . . Not until the converted nectar contains exactly 25 per cent. of water do the bees transport it finally into other cells. Before closing the full cell with its operculum a drop of venom is discharged into it from the sting to prevent fermentation. Thus the bees invented antiseptics before Pasteur or Lister! The honey thus treated and sealed can be preserved for years.

A certain number of honey-bearing flowers have a much elongated tube and except in unusually favorable weather the level of the nectar is too low for the bees to reach, though butterflies, whose trumpet is much longer, can rifle the treasure. Thus the flowers of certain widely cultivated plants, such as red clover, are practically useless to the apiculturist in spite of the great amounts of nectar they contain. This is why Langstroth recommended that progressive bee keepers should endeavor to breed bees with the longest possible tongues. These attempts have remained practically futile, but the bees have attempted to solve the problem by piercing the flower tube when they find its contents otherwise inaccessible. In most cases, however, their mandibles are too weak. But their rivals, the wild bumble bees, which also lay up honey, have strong jaws and when they have pierced the base or the side of such flowers as the bean and the pea, the aconite, etc., the bees profit by these artificial apertures to collect the nectar.

An experiment devised by me some years ago, which has been often repeated since then by others, proves the existence of the occult committee—the soul of the hive, as Maeterlinck says—which directs all the operations of the colony. I placed bits of sugar in a dark place accessible to bees, but far distant from any nectar bearing plant. After a certain lapse of time the pioneer bees which are sent out to explore the area in the vicinity of the hive discovered these and recognized their sweet nature; but their mandibles were too weak even to detach small particles. What would they do? I marked them on the back with water colors before they returned to the hive. At the end of twenty or thirty minutes the marked bees returned accompanied by other workers. I then perceived that they had not come directly from the hive; they had stopped on the way at a pool of water where they had filled their crops. They disgorged this water upon the sugar and calmly waited until a sort of syrup was formed, which I afterwards found to contain about 75 per cent. of water as does nectar. Not until the syrup was sufficiently concentrated did they suck it up and carry it back to the hive. From this moment a triple line of bees forming a triangle was organized: 1. From the hive to the pool; 2, from the pool to the sugar to deposit the water; 3, from the sugar to the hive. We have here a striking example of the collective, and not individual, intelligence of these interesting little creatures.

Last July this experiment was repeated by a curious chance on a much larger scale. The Paris-Lyons railroad passes by the laboratory of plant biology at Fontainbleu. One night a freight car loaded with granulated sugar was smashed near this point. When I got there and before I had found out what had caused the crash I was highly astonished to see clouds of bees rushing towards the railroad tanks, and the pools containing aquatic plants. The explorers had promptly discovered the presence of the booty and informed the various hives. Since the sugar was too coarse to be carried away by the bees, the latter had received orders evidently to transform it into syrup. This fortunate chance was all the luckier from the bees' point of view, since the season of 1918 was very bad for agriculture for various reasons. The busy workers displayed such an extraordinary activity, starting out as soon as possible in the morning and laying off work as late in the evening as possible, that at the end of four days not a single vestige of sugar remained upon the track. A few sparrows and a few human beings were tempted by the treasure, but the latter prudently retired when they saw the white mass grow black with bees, not knowing—fortunately for this unexpected booty for my hive—that bees never sting when gathering nectar.

European Reconstruction Demands

A STATEMENT advertised by the Guaranty Trust Co. (New York) points out the danger to American industries of overestimating the reconstruction needs of Europe. Except as regards certain raw materials and some machinery, France will provide for her own immediate reconstruction demands. The rebuilding of destroyed industrial plants will quite probably be postponed until trade has revived sufficiently to employ the pre-war producing capacity. There will probably be a greater scope for American (in common with British) industry in rebuilding Belgium, where the factories themselves have to be rebuilt before further reconstruction can be effected. Development in the Belgian Congo has been continued to such an extent that 40,000 tons of copper were produced last year. America must depend primarily upon American markets in adjusting industries to a peace basis.—*Electrical Review.*

Open-air splitting of the quarry blocks into large slabs

Squaring the larger slates after splitting to the required thinness

Platinum and Palladium In Brazil*

Account and History of Neglected Occurrences of These Rare and Noble Metals

By George F. Kunz

So much attention has deservedly been given to the important supplies of platinum and of the platinum metals that have derived from Colombia[1] that the deposits existing in Brazil have been somewhat neglected. In view of this it seems timely to offer some important information thereon, communicated by investigators who have carefully gone over the ground. Unquestionably platinum is to be found in many places in Brazil where its existence is still unsuspected, and when the deposits now known and the others which will be discovered later are systematically worked, Brazil will be able to contribute largely to the world's stock of the valuable metal, and also of the related metals.

The occurrence of platinum in Brazil was already known in 1801, when it is noted by José Vierra do Conto.[2] He notes the finding of the metal in the sands of the Lages, near Conceiçao, municipality of Serro (Minas Geraes), and in the Rio Abaete (Nova Lorena Diamantina). Doubtless at this time gold with palladium was sometimes mistaken for gold with a platinum content, since the former metal had not yet been determined. It was only in 1805, and more fully in 1800, that Wollaston gave a more detailed description of Brazilian platinum, calling attention to the fact that there were met with in the sands many microscopic crystals of zircon, considerably rolled, and contrasting sharply in structure with the grains of platinum which totally lacked the characteristic of being rolled.

A platinum locality in Brazil was reported as long ago as 1812 by the English mineralogist, John Mawe, who traveled in the interior of Brazil by authority of the prince regent of Portugal.[3] In the course of his journey he came to a place which he says proved one of the most interesting, in a mineralogical point of view, that he had hitherto visited. It was called Largos (sic), but also bore the name ouro branco (white gold) "in allusion to a granular substance, not unlike gold in size and weight, found in a gold washing in the bed of a stream. This substance, which has since proved to be platina, was discovered many years ago in the cascalhao (gravel) below the vegetable earth, and incumbent on the solid rock, accompanied with gold, and black oxide of iron." This composition induced the belief that it was gold united with some other metal, from which it could not be easily separated. As, however, the amount of gold was small, and no one then recognized the value of platinum, but little effort was made to utilize the deposit, which was finally abandoned.

Mawe secured a specimen of the substance, and states that it seemed to contain osmium and iridium, and that the grains were rougher than those found in the Province of Choco, Colombia. He suggested that as the substance was at the time of this writing known to be platinum, work could scarcely be profitably resumed, "as the demand for that article is at present so small that the quantity sold would hardly pay expenses."[4] What a difference from the state of things at present.

Just after a blast in an underground chamber of the quarry

The masses of loosened slate are being hoisted out, and on the platform boring machines are being set in new position. Light is furnished by an unscreened electric arc.

The platinum found in the Rio Abaete, State of Minas Geraes, Brazil, and in greater quantity in its tributaries, is pronounced to be strikingly similar to that if the Urals, although the deposits of this metal from Condado differ markedly in this respect. According to Dr. Eugen Hussak the character of the occurrence in the first-named deposits may be thus formulated.[5]

1. Richness of the fine and heavy sands in iron minerals, magnetite, chromite, and also to a characterestic extent in perovskite.

2. Occurrence of olivine ricks, with lherzolite and picrotoporphyros, in the surroundings of some affluents of the Rio Abaete, which are known to be platiniferous and which rise in the Serra da Matta da Corda.

3. Similarity of the chemical composition of the platinum, as well in richness in iron, and thus in specific gravity, as in magnetic action.

4. Structural similarity of the platinum grains in both occurrences in the Urals and in the Rio Abetae. When they are larger than 1 millimeter they show themselves to be much rolled, while in the finest sands there not rarely appear minute crystals, clearly formed, of iron platinum and osmiridium.

5. Finally, a likeness consisting in the regular inclusions as described in the platinum of Nizhne Turinsk, of particles of osmiridium, having six clearly defined faces, parallel to the octahedral faces of the cubic crystals of platinum.

An analysis of a combined specimen of magnetic and nonmagnetic platinum (the latter in small proportion) gave the following results:

	Per cent.
Insoluble residuum	7.57
Iron	9.62
Palladium	trace
Copper	trace
Metals of the platinum group	82.81
	100.00

The specific gravity of this platinum, simply isolated and freed from gold, was determined to be 17.5.

The region whence comes the platinum of Condado, municipality of Serro, Minas Geraes, is situated at the foot of the Itambe de Serro, whence flows the stream Bom Successo. A nugget of platinum the size of a nut was found in this locality, and after having been shown in the exposition of 1889 it was placed in the museum of the School of Mines of Ouro Prato. The bed of the little stream Bom Successo is formed of schistose quartz, with a strong dip; in some places this is traversed by formations of amphibolized diabase, precisely as occurs in the neighborhood of Diamantina. The minerals accompanying the platinum are also similar to those of that diamantiferous region, and may be classified as follows:

1. In the finest sands: A quantity of zicron, rolled, colorless or partly pink; a great deal of oligiste (specular iron ore) and octahedra of magnetite; a number of fragments of black tourmaline; rare fragments of rutile; and crystals of monazite.

2. In the coarse sands: Rolled quartz in quantity, generally large pieces; fragments and aggregations of black tourmaline, the "feljão" of the miners of Diamantina; a considerable quantity of xenotime, as well prims of octahedra; much hematite, oligiste, martite, and pyrite, but no anastase.

3. Very rarely there are also met with disthene, zircon, and colombite.

*Reprinted from *Bulletin of Pan American Union* (Washington).

[1] "Platinum and its relation to Latin America," by George F. Kunz, *Bull. Pan American Union*, November, 1917, pp. 4-23. "Platinum, The World's Present and Past Supply," by George F. Kunz, Mineral Industry, 1917, pp. ———. "Platinum, The World's Present and Past Supply," by George F. Kunz, Mineral Industry, 1918, pp. ———.

[2] "Memoria sobre as minas da Capitania de Minas Geraes," written in 1801, first published in 1842 in Rio de Janeiro, see pp. 1215, 122.

[3] John Mawe, "Travels in the Interior of Brazil, particularly in the gold and diamond districts of that country, by authority of the Prince Regent of Portugal," London, 1812, pp. 157, 209.

[4] Mawe adds later on (p. 277): "Platina may be obtained in tolerable quantities at Largos, but the place which produces it has been abandoned from want of a market."

[5] Eugen Hussak, "O palladio e a platina no brazil," Port. trans. by Miguel Arrojado Ribeiro Lisboa, and Manoel Arrojado Ribeiro Lisboa, Annaes da Escola de Minas de Ouro Preto, No. 8, 1906, pp. 181, 182.

In view of the perfect conformity of the occurrences here and at Tijucal, Dr. Hussak attributes both to the same source, emphasizing the fact, however, that in no case can we think of a primary formation, such, for example, as a secretion from an eruptive basic rock, rocks with olivine and gabbro, since the forms of the platinum clearly indicate that we have to do with some secondary formation. Probably we have here a deposition of platinum in solution, derived from the decomposition of platiniferous pyrites, or of a combination similar to sperrylite, minerals originating from the schistose quartzes of the neighborhood, or from the upper conglomerate quartzes. The specific gravity of the Condado platinum, from specimens weighing 0.312, 0.267, and 0.2492 gram, is demonstrated to be 15 to 15.75, differing notably from that of the Tijucal platinum.[6]

Among the various platinum localities of Brazil may be noted Gongo Secco, where it appears in the auriferous jacutinga, between the itabirites; the River Bruscasin in Pernambuco, in gold-bearing quartz among crystalline schists; the east side of the Espinhaco, from Itambé de Matta Dentro to Itambé de Serra, State of Minas Geraes, in the dimantiferous cascalho; the Abaeté river and its tributaries, where the deposits come mainly from olivine matrices; the veins of primary schist at Serro, Minas Geraes, and the alluvial deposits of the Matto Grosso rivers, State of Parahyba do Norte.[7] The wide dissemination and the varied character of the formations in which Brazilian platinum occurs would seem to preclude the advisability of confining the search for it to any one of a number of possible localities, and its discovery here or there will probably continue to be, as it has been in the past, dependent upon its recovery in the course of mining operations for other deposits.

A number of manuscripts, charts, and designs believed to contain some interesting and valuable information upon the platinum deposits in Brazil appear to be buried either in the archives of that country or in those of Austria. They represent the result of years of investigation pursued in Brazil by Virgil von Helmreichen, an Austrian mining engineer, who was occupied in this region from 1831 to 1851, during which period he traversed a wide extent of Brazilian territory. His long residence in the State of Minas Geraes coincided with the most brilliant epoch of the gold-mining industry—that of the exploitation is the subterranean mining in Gongo Secco, Cata Branca, Morro Velho, Itabira, and Condado—and it was while in the service of the English mining companies that he had an opportunity to make valuable observations regarding the deposits. The fact that most of these mines were later abandoned makes the loss of von Helmreichen's notes especially regrettable. Many of the items were contained in a correspondence he carried on with Hocheder, the engineer and geologist of the English mines. Among the few papers of the Austrian engineer that have been preserved in print are "Reisebericht aus Minas Geraes von 6 Mai 1846," and "Ueber das geognostische Vorkommen der Diamanten und ihre Gewinungs-Methoden auf Serra do Grão Mogol." This latter is one of the most excellent of the older contributions to the knowledge of these deposits.

On Helmreichen's death Wilhelm Heidinger, then president of the Vienna Academy of Sciences, caused his manuscripts to be sent to Vienna to be deposited in the academy. However, when, in 1896, Prof. Suess, Heidinger's successor, made an examination of them, he discovered that precisely the geological portion referring to Brazil had disappeared, and he learned that this had been sent to the Brazilian consul at Dresden to be copied out. Shortly after this the consul died and all trace of the manuscript has been lost. It is believed, however, that there should still exist copies, made in Brazil before the originals were sent to Europe, but all efforts to find these in Brazilian archives have proved fruitless.[8]

The existence of palladium and gold in the granite of Candonga, Minas Geraes, as early as 1875, was reported by W. J. Henwood.[9] His details were almost exclusively derived from a manuscript of V. von Helmreichen, who had been active for many years in the mines of Minas Geraes. He noted that in the granite of Candonga there were disseminated sparsely grains of gold in a mixture of quartzite, feldspar, and magnetite. At times the auriferous rock entirely lost its granitic character, owing to the diminution of the quartz and the predominance of the magnetite. The particles of gold were irregularly distributed and formed an alloy containing from 5 to 8 per cent. of palladium, the color being a yellow so light as to make the metal in some cases resemble native silver.

From these and other data furinshed by von Helmreichen, Dr. Hussak reaches the following conclusions:[9]

1. That the auriferous rock of Candonga forms deposits included in the itabirite which plays an important part in the formation of the Serra of the same name.

2. That these itabirites, as well as the auriferous deposits are traversed by granite veins, certainly outcrops of recent granites which exists in the depths. Von Helmreichen states that granite was here observed even above the itabirite.

3. The gold was unequally distributed, sometimes appearing concentrated in clumps in a rock characterized by a yellow silicate (gehlenite); sometimes, however, this is lacking in gold.

4. That the gold of this deposit is marked by its relatively high palladium content.[10]

In the Morro Velho mine at Villa Nova de Lima, Minas Geraes, Brazil, said to be the greatest gold producer in the State, there are many occurrences of what is locally called ouro blanco (white gold), which consists of an alloy of gold and palladium. Although this is met with in many places it is nowhere found in abundance. This mine is operated in a vein in the Piracicaba schist.[11]

An altogether exceptional example of a platinum nugget was found in the Approuague River, French Guiana. An analysis of it by A. Daumer[12] gave platinum, 41.96; gold, 18.18; silver, 18.39; and copper, 20.56 per cent.

VALUABLE COUNTERFEITS.

Although the gold used in making the following imitation coins scarcely came from Brazilian mines, their existence is a matter of some interest.

Counterfeit United States gold coins struck (never cast) in platinum, which was then plated with gold, have turned up at the Philadelphia mint from time to time. In some cases there was a small admixture of silver in the platinum, as this small quantity of silver would not reduce the weight unduly. The vicissitudes of metal values are illustrated in the experience of Mr. Eckfeldt, assayer at the mint, who last year sold a number of counterfeit eagles and half eagles he had collected in past years at a large profit. These pieces dated in 1850 were of platinum gilded. That such pieces are still at large, though very rare, is proven by the recent detection, among the uncurrent gold coins sent in for recoinage to the Philadelphia mint, of a half eagle counterfeit in gilded platinum, dated in the sixties. This piece reached Philadelphia from the Chicago subtreasury and had circulated for some years without detection. Of course it could now be sold for several times the value of the genuine gold coin.[13]

That this adulteration of the United States gold coinage with platinum was practiced in 1850 suggests that the platinum may have been found in connection with the gold-mining operations in California and Oregon. As the less valuable metal it may often have been thrown away by the miners who secured it or was sold very cheaply. The silver in these spurious coins may, of course, have been an impurity. However, silver was both cheaper and of lighter weight than platinum, and the admixture would bring down the weight of the composition to a close parity with that of gold.

Splitting and shaping the smaller roofing slates

Note the special sabots worn by the splitter in this view. The moveable straw screens protect against the wind. The splitters are the aristocracy of the quarries, and hand their craft secrets from father to son.

Polishing panels and slabs of slate for lavatories and interior finishings

Views of the Slate Industry of the Anjou

Our frontispiece and the views on the two present pages illustrate the workings of the ancient slate mines of the Anjou. They come from the vicinity of Angers on the Loire in the Departement Maine-et-Loire, and have a double interest for us. In the first place they testify to the revived activity in this industry under the spur of interrupted foreign commerce; and in the second place they illustrate underground slate workings, which are a type not often met in the United States. Were we not warned to the contrary, or very familiar with the appearance of slate ledges, the view shown on our front page would remind one of an ore mine or an excavation tunnel.

It is of interest to note that the underground power is electric, and that the light both for auger men and hoisters is a naked arc light. It is safe to assume that hoist and grinding machines are also driven by electricity.

Coming to the open-air work, there is nothing on our illustrations of peculiar interest. We find the French using wind and sun screen of grass and reed which are cheaper than cloth, cooler and cheaper than corrugated iron, and just as effective as a stone wall. Evidently the splitter finds the customary wooden sabot a comfortable and convenient shoe for his work; the upper view on this page shows what is evidently a special pattern in them, designed to assist in holding the small slabs firmly while splitting them.

[6] Eugen Hussak "O palladio e a Platina no Brazil," Port. trans. of Miguel Arrojado Ribeiro Lisboa and Manoel Arrojado Ribeiro Lisboa, Annaes de Escola de Minas de Ouro Preto, No. 8, 1906, pp. 167-169.

[7] J. C. Oakenfull, "Brazil in 1911," third annual ed., February, 1912, London, n. d., p. 292.

[8] Preface of Miguel Arrojado Ribeiro Lisbôa to E. Hussaks's O Palladio e a Platina no Brazil," Annaes da Escola de minas de Ouro Preto, No. 8, 1906, pp. 79-84.

[9] "Observations on metalliferous deposits," Penzance, 1871, vol. 1, p. 175.

[10] Eugen Hussak, "O Palladio e a Platina no Brazil," Port. trans. by Miguel A. R. Lisbôa and Manoel A. B. Lisbôa, Annaes da Escola de Minas de Ouro Preto, No. 8, 1906, pp. 99-103.

[11] E. C. Herder and R. T. Chamberlain, "The Geology of Central Minas Geraes, Brazil;" reprinted for private circulation from "The Journal of Geology," July-Augu., 1915, v. 23, p. 412.

[12] Comptes Rendus 1861, v.52, p. 682.

[13] Communicated to the writer by Dr. T. L. Comparette, of Philadelphia mint, in letter dated May 31, 1917.

The Design of Artillery Ammunition*

The Major Considerations to Which the Ordnance Man Must Give Weight

By J. Wallace Taylor of the Frankford Arsenal

THE design of artillery ammunition demands a thorough knowledge of the laws of mechanics, the strength of materials, the practice of machine design, the behavior of explosives, and the science of ballistics. This subject is probably more intimately connected with mathematics than any other practical subject in which men are engaged, and the mathematics involved is very elaborate. However, I shall endeavor to give a general idea of the subject as free from mathematics as possible.

A round of ammunition consists of a primer, igniter, propelling charge, projectile, fuse and bursting charge. A cartridge case is commonly added, which ties the entire round together as a unit, when it is called fixed ammunition. Fixed ammunition is used up to and including 6-inch, though not usually in sizes much over 3 inches in diameter. In the larger sizes the powder or propelling charge is done up in bags and handled independently of the projectile. These bags are not only for convenience of handling but also are to enable a variation of the charge corresponding with the different zones of fire.

EXPLOSION AND DETONATION OF EXPLOSIVES.

Naturally the principal component of ammunition is the explosive. This owes its explosive power to its ability to expand rapidly in volume by changing from a solid or liquid to a gas. Its energy is dependent upon the heat evolved in the explosive reaction, but its power depends upon the time in which this takes place. But whether combustion is rapid or slow, it proceeds in pretty much the same manner. The powder mass can burn only after it has been heated to the temperature of inflammation. This heating proceeds on account of the heat developed by the layers first burnt. The heating is proportional to the difference between the temperature of the burning substance and the gases in contact; and the more rapidly the mass is heated the more quickly it burns. The heat of the gases is proportional to their temperature, in turn proportional to the pressure; and thus the speed of combustion is proportional to the pressure under which the reaction takes place, up to the ultimate limit of simultaneous ignition. The true limit, however, is considerably below simultaneous ignition. The limit of the rate of propagation of combustion of the explosive is the velocity of projection of the gaseous molecules, if the whole energy of the thermal reaction were converted into the translation of the molecules.

When the velocity of combustion approaches these higher limits it is called a detonation. All explosives require some confinement to enable them to build up sufficient pressure to get up to speed. When the higher limits of velocity are reached no further confinement or assistance is necessary, as the very inertia of the generated gases themselves acts as sufficient confinement to maintain the required pressure around the active zone. Some explosives will invariably detonate, others need considerable assistance. And still others cannot be detonated under any practical circumstances. If an explosive of the first class is ignited by flame it first burns in an ordinary way, but in an almost infinitesimally small space of time detonation takes place. Explosives of the second class lack the capacity to accelerate burning through the intermediate stages to the detonating stage, and require the assistance of an explosive of the first class to bring them up to effective action. The third class of explosives practically cannot be detonated at all but will explode with very effective rapidity, and the time element in the explosive reaction is sufficient to make it possible to control their activities.

All chemical changes tend toward the formation of the system that liberates the most heat. All forms of energy, potential and kinetic, tend to run down hill to the lowest level and expend themselves. Thus, an explosive tends to produce the greatest volume of gas and the maximum amount of heat. In a low-order detonation the carbon is largely burnt to CO, the nitrogen is only partially liberated and a thin whitish smoke is given off. In a high order detonation a larger portion of the carbon is burnt to CO_2, the nitrogen is fully liberated and as the oxygen supply is limited some of the carbon is necessarily left free, appearing as a heavy black smoke. The increased energy and activity can be partially accounted for by the fact that the combustion of one molecule of carbon to CO_2 is equal to the heat produced by about four molecules of carbon burning to CO, not to mention the increased heat obtained from the more complete liberation of the nitrogen.

THERMAL CONSIDERATIONS.

As a rule, the heat of combustion is the only thermal chemical reaction that concerns the engineer. However, the oxidization of an element is not the only reaction producing heat. Every chemical and physical change which occurs in any substance is accompanied by a thermal manifestation. The chlorinization of potassium, for instance, produces more heat than its oxidization and even more than the oxidization of carbon. The sulphurization of potassium develops more heat than either the oxidization of potassium or sulphur. On the other hand, the oxidization of nitrogen absorbs heat. This thermal effect which accompanies the chemical reaction in the formation of a compound is called the heat of formation. But the heat of formation is only half of the story; the heat

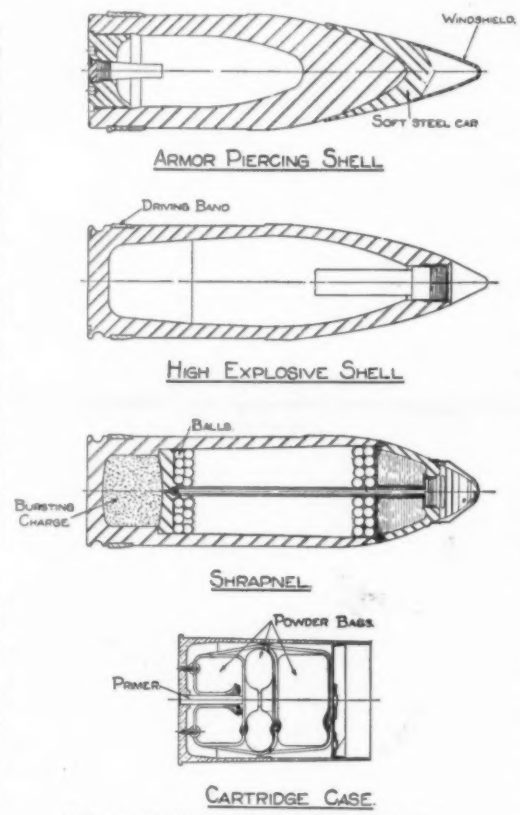


Fig. 1.—Typical ammunition of several types, fixed and unfixed

of dissociation must also be considered. Most substances give off heat in their formation, which is called an exothermic reaction. Many substances absorb heat in their formation and are called endothermic. An exothermic substance, therefore, having given off heat in its formation, will absorb heat during its disintegration, while an endothermic substance, having absorbed heat in its formation, will give off heat during its disintegration. Thus the heat liberated in any transformation accomplished through successive reactions is the algebraic sum of the heats liberated in the different reactions. In other words, the heats of formation on both sides of the equation must be taken into account in estimating the heat evolved by any transformation. The heat of explosions is the difference or balance between that represented on the two sides of the chemical equation. This heat available is expended in raising the temperature of the chemical components, in fusion and vaporization and in internal and external work. The amount of heat expended in fusion and vaporization depends upon the composition. The amount of heat expended in raising the temperature is dependent upon the specific heats of the chemical components involved, and the specific heats of both solids and gases vary with the temperature.

EXPLOSIVES.

An explosive chemical compound is invariably a nitrogenous compound. Both the heat of formation and the stability of these compounds are very low. The amount of nitrogen present is a fair index of the energy of the explosive. These compounds are also usually deficient in oxygen for a complete oxidization of the reaction, not as an advantage but as an unavoidable condition. Nitroglycerine, a favorite with bank robbers, has an excess of oxygen of over 6 per cent., while T.N.T. is deficient in oxygen by over 60 per cent., both having about the same percentage of nitrogen. The nitroglycerine is the more powerful explosive and is very much more sensitive. Fulminate of mercury is deficient in oxygen by over 50 per cent. and contains over 40 per cent. less nitrogen than nitroglycerine. It is, however, equally sensitive with nitroglycerine. It is not as powerful as T.N.T., and its energy is comparatively low, but its rate of detonation is sufficient to make it a powerful explosive. Mercury fulminate is the most satisfactory explosive for primers or detonators we have. It is about as sensitive an explosive as can be used in practice. It is a very heavy compound and its explosion is like the sudden transformation of solid metal into gas. It has the power of accelerating a feeble initial impulse into a violent detonation, sufficiently brusque to bring up to speed the most inert explosive. Guncotton is also a straight chemical compound. It is a nitrated cotton just as nitroglycerine is a nitrated glycerine. It is a powerful high explosive that requires a detonator to bring it up to its maximum activity. Nitrocellulose, or smokeless powder, is quite similar to guncotton, with the exception that it is of considerably lower degree of nitration. It is a progressively burning powder that practically cannot be detonated, which makes it a valuable propelling charge for firing projectiles from guns. Decanitrocellulose, or service powder, is deficient in oxygen by about 30 per cent. This is likely to lead to "hang fires" and "flarebacks" when working the guns in rapid-fire work unless proper precautions are taken.

An explosive mixture in distinction to an explosive chemical compound is a mixture of explosive compounds and oxidizing agents or entirely a mechanical mixture of non-explosive reducing and oxidizing agents forming an explosive combination. Under this head falls our indispensable black gunpowder, the large majority of primer compositions and practically all of the explosives used in mining and quarrying operations.

PRIMERS.

Primer compositions are mechanical mixtures. They usually have an explosive compound as a base, which is almost invariably mercury fulminate. In a primer charge a reasonable sensitiveness is wanted combined with heat and activity ranging from an igniting to a detonating charge, depending on its purpose. The addition of potassium chlorate to mercury fulminate slightly increases its sensitiveness, supplying oxygen to the fulminate, which is quite deficient in oxygen. This almost doubles the amount of heat available, but prolongs the action considerably. However, this is favorable for primer action, as a slight prolongation of action is advantageous to ignition. The addition of antimony sulphide to fulminate and potassium chlorate increases the sensitiveness still further and also prolongs the action. The majority of primers are composed of these three compounds.

There are three main forms of primers; ignition, friction and percussion. Ignition primers are usually electrical and are used for igniting the propelling charges in large guns. Friction primers are also cannon primers, and, as the name implies, are fired by the generation of heat by friction. The composition contains some 10 per cent. of ground glass. The friction caused by the abrasive when a serrated plunger is drawn through the composition is sufficient to ignite the composition.

The percussion primers are fired by the blow of a firing pin. They are grouped into two general designs, anvil and stab primers. The principle of action of the two is the same. The movement of the firing pin is retarded by the composition, thus converting mechanical energy into heat which is localized at the point of the pin as to reach the ignition temperature.

The anvil primer has a comparatively thin layer of composition superimposed upon a metallic bed or

*Presented before the Technology Club of Phila., at the Engineer' Club of Phila., and reproduced from the *Journal of the Engineers' Club.*

anvil. You will notice this type of primer in any .32 caliber revolver cartridge. Because the composition is shallow in this primer, the firing pin is made somewhat blunt to insure its coming in contact with a sufficient amount of composition to make good its chances of functioning.

The stab primer is a plain metallic cup filled with composition. This type of primer is usually used in artillery fuses for bursting shell. The composition is covered with a thin metallic disk to confine the composition and yet allow ready penetration. The depth must be such that the sharp firing pin will be completely retarded within the composition. Though this pin is sharp it is not sharpened to a "feather edge." Its energy per unit area of point is very much greater than that of the anvil-type firing pin, and to this characteristic the increased sensitiveness of the stab primer is due.

The sensitiveness to ignition of a charge decreases with its loading pressure; the more highly compressed charge offers a solid impervious front from which the heat is quite rapidly conducted away. However, the sensitiveness to impact is increased with the loading pressure; the harder material offers a greater resistance to penetration. It brings the striker to rest through a shorter space and in a shorter interval of time, thereby obtaining a greater amount of power or activity with which to initiate the explosive reaction. If a pickaxe is driven into a sand bank it will enter clear up to its eye, but it will have been retarded so gradually that neither the sand nor the pick will show any appreciable rise of temperature. Now, if this same pick is driven against a stone wall it will make only a slight indentation, but both the point of the pick and the scar on the stone will have become so hot that should any small particles of stone fly off they will be red hot. For this reason stab primer compositions are pressed up under heavy pressure running from 10,000 to 100,000 pounds per square inch.

COMPARISON OF CHARACTERISTICS OF EXPLOSIVES.

A comparison of a few characteristics of explosives is given in Table I, based on one pound of explosive. The temperatures of explosion are high when compared with the usual temperatures met in engineering; they temperatures of explosion are high when compared with some of the stars, since the sun is a comparatively cold star at 9600° F. The volume of gas generated, if reduced to standard temperature, is not especially large. The heat of explosion is quite low if compared with the heat of combustion of our ordinary fuels. The pressures developed are very high, but they can be duplicated and exceeded by other means. The velocity of detonation is also very high, as velocities ordinarily go. To be sure it is not to be compared with the wave velocities of electricity or light at 190,000 miles per second; still, as a velocity of combustion it is in a class by itself. The most startling characteristic of an explosive, especially of a high explosive, is its power. It has no comparison. It seems almost inconceivable that one pound of T.N.T. can develop 200,000,000 horsepower. Its explosion will shatter the mightiest gun. The amount of energy is ordinary, but the intensity is very remarkable. The infinitesimal interval of time in which the energy is developed makes its power tremendous, for power is the rate of doing work.

PROPELLING CHARGE.

Returning now to our round of ammunition, we have the primer, which is set in action by the impact of the firing pin. This in turn ignites the black powder igniter, developing a large volume of gas at high temperature and good pressure to drive deeply into the smokeless powder charge and thoroughly stir up the powder grains; thus insuring prompt inflammation of the entire charge. In small guns the igniter is combined with the primer; in large guns it is put up in several small bags and distributed throughout the propelling charge. The igniter is necessary because smokeless powder burns very feebly at atmospheric pressure, though its combustion increases rapidly with a rise of pressure. Black powder is not affected to so great an extent by pressure as is smokeless powder and burns very vigorously even at atmospheric pressures. Any irregularity or delay in the inflammation of the entire charge will cause irregularities in the velocity of the projectile and the accuracy of the gun will be lost.

Smokeless powder is a progressively burning powder, and the progressive combustion can be further increased

TABLE I

Explosive	Temperature of explosion	Volume of gas at temperature of explosion	Heat of explosion	Pressure exploding in own volume	Velocity of detonation	Power of explosion
	Degree Fhr.	cu. ft.	B T U	lbs. per in.²	Ft. per sec.	Horsepower
Trinitrotoluene (T.N.T) $C_7H_5(NO_2)_3$	4500	157	1320	240,000	23,000	200,000,000
Mercury fulminate..... $C_2N_2HgO_2$	6300	69	660	250,000	16,300	95,000,000
Smokeless powder..... $C_{30}H_{30}(NO_2)_{10}O_{20}$	5000	158	1750	216,000		
Black powder..... $16KNO_3+21C+7S$	4700	43	1210	125,000		
Illuminating composition $3Ba(NO_3)_2+10Al$	17,700					

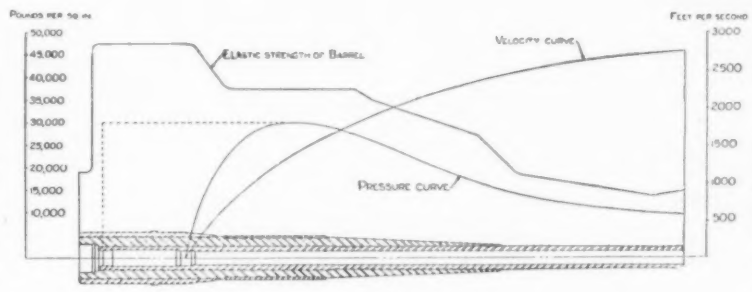


Fig. 2.—Pressure and velocity curves for a gun of medium caliber

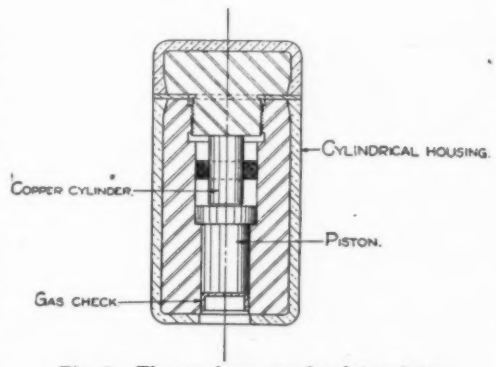


Fig. 3.—The crusher gage for determining interval pressures

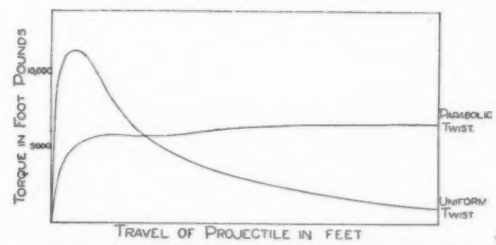


Fig. 4.—The load on the rifling of parabolic and of uniform twist, in gun of medium caliber

by the design of the powder grains. The evolution of gas depends not only upon the pressure under which combustion takes place but also upon the area of the burning surface. A solid cubical or cylindrical grain will burn with a decreasing surface. A hollow cylindrical grain will burn with constant area, for the inner surface increases as the outer surface decreases. A cylindrical grain with several longitudinal perforations will burn with an increasing surface, as the sum of the inner surfaces will increase faster than the outer surface decreases. The British service powder, cordite, is a cylindrical grain with a single perforation and gives a constant rate of burning. The American service powder is a cylindrical grain with seven longitudinal perforations, giving an increasing rate of burning.

The object of endeavoring to obtain as progressive combustion as possible is to keep up the pressure behind the moving projectile. It is, of course, necessary to have sufficient initial surface to give practical initial pressures. Using modern progressive powders, it is possible with five expansions to obtain mean effective pressures of over 75 per cent. of the maximum pressure. A steam engine cylinder at five expansions gives a mean effective pressure of only 50 per cent. When speaking of gas expansions in the gun, the volume of the powder chamber is taken as the unit and considered as one expansion. The expansion line in an engine is practically adiabatic, but in a gun it is considerably above this, for the powder is burning throughout the travel of the projectile and heat is also being added by the re-formation of the products of combustion. This expansion line is shown in Fig. 2. The powder must be designed to impart the maximum energy to the projectile, keeping within the working stresses of the gun, and to be entirely consumed by the time the projectile leaves the muzzle.

The thermal energy utilized in propelling a projectile from the gun varies from 17 per cent. to 33 per cent. The heat lost in the walls varies from 5 per cent. to 30 per cent., varying inversely with the size of the gun. Considerable energy is also expended in the recoil of the gun and in giving velocity to the gases; but the greatest part of the heat, as in the engine, is lost through the exhaust or muzzle.

As mentioned before, the products of combustion of smokeless powder are deficient in oxygen, and their coming in contact with the atmosphere greatly increases the muzzle flash. For this reason machine guns and some of the smaller artillery pieces used flash shields in the present war. Smokeless powder does not betray itself by smoke, but it does by its flash. The muzzle flame near by is blinding and at a distance behind hills and forests it is as prominent as sheet lightning. Promising steps have been taken, however, to overcome this. The effect of the muzzle blast of a gun has an accelerating influence on the projectile up to about 100 calibers.

PRESSURES AND VELOCITIES.

All lots of powder are proved by ballistic test before acceptance. This test consists of obtaining the maximum pressure developed in the bore of the gun and in obtaining the velocity imparted to the projectile. The pressure is obtained by the use of a crusher gauge placed at the back of the powder charge (see Fig. 3). This gauge consists of a strong cylindrical housing with an accurate piston and gas check. Between the piston and the head of the housing is placed a calibrated copper cylinder which is crushed under the pressure exerted by the gases on the piston. From the deformation of this calibrated copper cylinder the maximum pressure developed in the gun is determined. These coppers are so standardized that the movement of the piston is reduced to a minimum and very consistent results are obtained. The maximum pressures used in modern guns run 30,000 to 49,000 pounds per square inch, depending upon the design. The muzzle velocity of the projectile is obtained by placing two wire screens in front of the gun. The instant the projectile pases through the screen is recorded electrically on a chronograph, and from the time interval recorded and the distance apart of the screens the velocity is readily found. The muzzle velocity of the projectile in modern guns runs from 1,700 to 2,700 feet per second, varying with the design and charge.

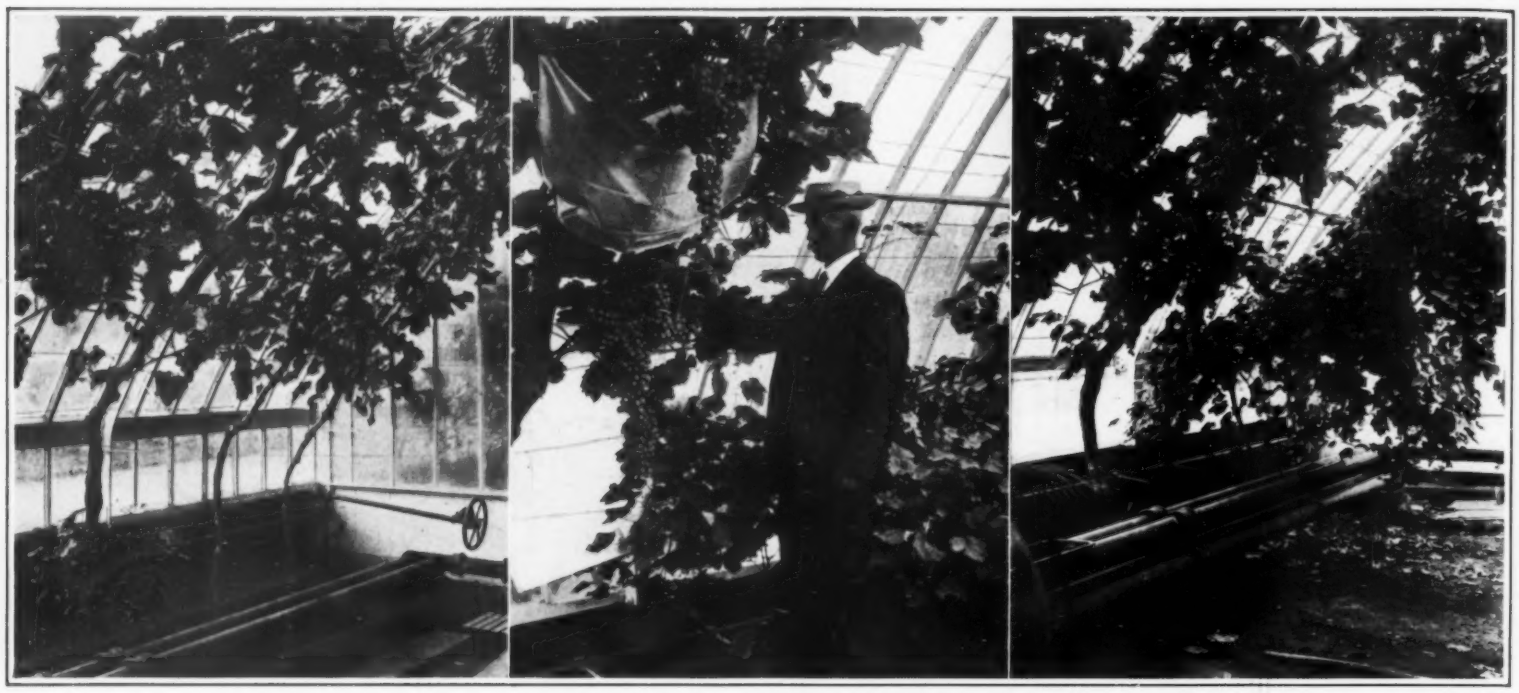
LIFE OF GUNS.

A desirable feature of a powder for propelling charges is to develop the required gas volumes and pressures at the lowest possible temperature, to minimize the tremendous eroding effect which the hot gases have upon the bore of the gun. This erosion is serious. It allows the leakage of the gases past the projectile as well as destroys the rifling, which results in loss of accuracy. With the small-arms rifle a sharpshooter will not use a gun for over 3,000 rounds, although the accuracy is good for ordinary battle ranges for over 15,000 rounds. In machine-gun work, however, the tube is good for usual service of over 100,000 rounds, with records of 10,000 per hour in battle. The useful life of larger guns, however, is nowhere near such a number of rounds.

RIFLING IN GUNS.

All modern guns are rifled. The rifling in the smaller calibers is usually given a uniform twist of about 7°. The larger calibers are given a parabolic or gradually increasing twist from one turn in 50 calibers to one turn in 25. The bore of a gun is the inside diameter of the lands of the rifling. In medium caliber guns the grooves are several hundredths deep and the diameter of the copper driving band is larger than this by several hundredths of an inch. So it can be seen that it will take considerable force to make the band conform to the bore. This initial broaching or squeezing

(*Continued on p. 31*)



Converting one variety of grape into another, by means of scientific inarching, without the loss of a single crop

The Fruit-Grower's Sleight of Hand

Some of the Things That Are Accomplished by Skillful Grafting and Related Processes

(Photographs Copyrighted by Brown and Dawson, New York)

GRAFTING is an operation in which two cut surfaces of the same plant, or of different plants, are placed so as to unite and grow together. The cutting, or portion cut off for transfer to a new stock, is termed the scion, or graft, and the rooted plant, on which it is placed or worked, is called the stock.

The art of grafting is of great antiquity, but it is not known by whom it was invented. It is spoken of by Theophrastus, Aristotle, Virgil, and other ancient authors. It would appear, however, from their writings, that the principles were very imperfectly understood. Otherwise they would not have entertained the belief that the vine could be grafted on walnut or cherry, and the peach on the willow; or that black roses would be the result of grafting on black currants; for these plants, having no natural affinity, can never form a vital union, however accurately they may be mechanically joined.

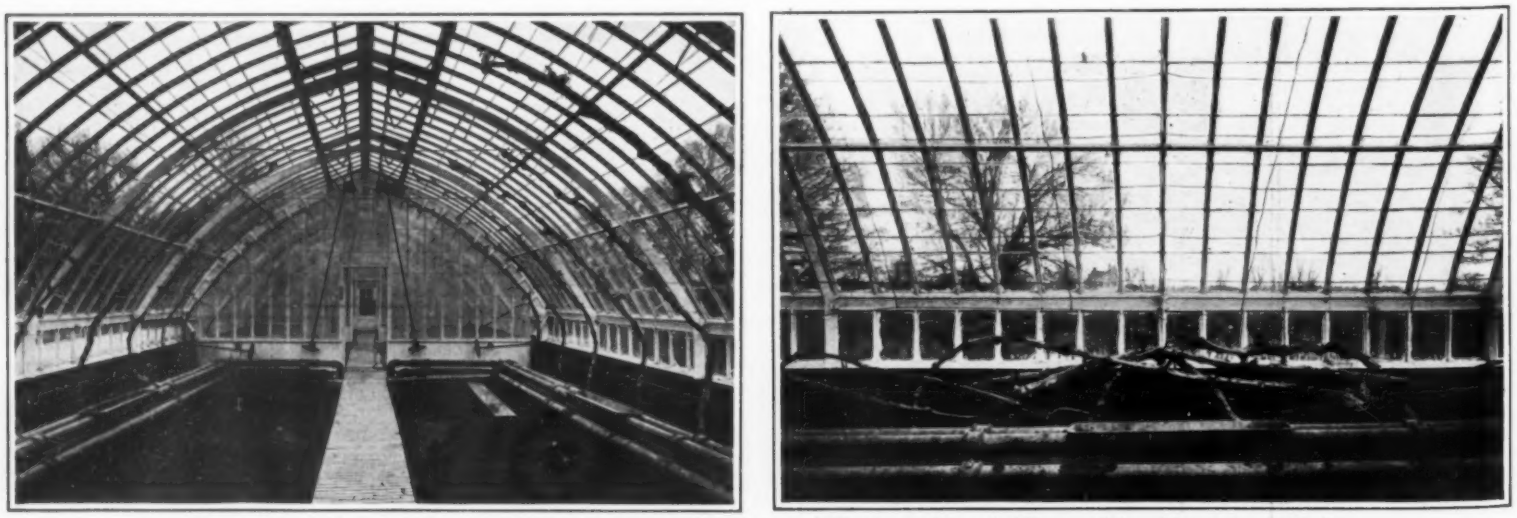
The modes of grafting are numerous, but they all depend on one principle which should be well understood. But, previous to explaining this, it must be remarked that wood does not unite with wood to form a vital union; for, after trees have been grafted for many years, it is found that between the portions of the wood of the scion and the wood of the stock, which had been placed together, at the time of grafting, no union has ever taken place. Organic mucus or cambium is a viscid secretion present in all living parts of plants, and from it all their organs are formed. It is most readily observed between the bark and the wood of exogenous trees in spring. From this substance a cell is formed, and the earliest condition of a plant is a single cell. This cambium or organizable matter is what forms the union in all modes of grafting and budding. It also forms the callous on cuttings before roots are emitted.

Some years ago the editor of the *Journal of Horticulture*, Dr. Hogg of London, gave several instructive articles on this subject. He claimed that the cambium had to go through several changes after grafting, and become cellular, or vascular tissue according to the genera of plant worked upon, and that no union would take place until most of these changes had been gone through.

Grafting and budding are carried out for various reasons, but the most common one is to put a choice variety of fruit or flowering plant on roots that are hardier than its own; many of our finest varieties of fruit trees do but poorly on their own roots, where conditions are not for their best advantage. The art of grafting is used to change fruit trees, already established, into other or more desirable sorts, and also to strengthen or retard growth, as the case may be. Thus, peaches are worked on plum stock, for forcing purposes, as they do not make so rank a growth as would be the case on their own roots. Pears are worked on quince for low, heavy or ill-drained localities, and for higher land, on pear or apple seedlings. Thorn and mountain ash have also been used for pear stock, for very dry or gravelly subsoil. So there is always a reason for the work, apart from the pleasure of doing it.

Cleft grafting is most commonly practised on established apple or pear trees. Small branches, or side shoots are better than wood six inches or more in thickness. The grafts will "take" on either, but those on the small wood are in less danger of being blown off after the first year's growth. Grafting is most successful if done when the sap has started, but before the buds show the green. Whip-and-tongue grafting forms the best union on seedlings, or two-year-old stock. The stock to be grafted on should be gone over a week or two before the sap starts to move, and cut back to about where they are to be grafted. Young stock one inch or so in thickness can be left at this cutting, about nine inches from the ground; larger stock, if straight, can be left any desired height, for standards, up to five or six feet, but the low grafted stock will in most cases come out ahead. Plums, apples and pears can be worked the same, so far as the operation is concerned, but plums should have damson or plum stock.

Budding is an operation by which a bud, together with a portion of bark, is removed from a plant, and inserted beneath the inner bark of another plant, or beneath that of the same plant; this operation is sometimes performed where the natural buds do not push to form shoots, at places where these are necessary. As in grafting, only nearly allied species or genera will succeed when budded on each other. The main principle of budding is the same as in grafting. The



Two views of a large nursery near New York, where all the latest wrinkles in grafting, budding, and inarching are practised

union is effected by means of the organizable matter, or cambium, which exists between the alburnum and inner bark; and the success of the operation depends upon the abundance of that matter being such as to permit of the bark being easily raised from the wood. When both the stock and the tree from which the bud is taken are in that condition the union is most readily effected. Buds are generally inserted in July or August, in which case they remain dormant, or at least do not push into shoots until the ensuing spring.

The modes of performing the operation are many; the principal ones are shield, or T-budding, inverted T-budding, square shield, flute, ring budding, etc.

Shield or T-budding is the best and most quickly made for most purposes. In operating, take a shoot from the tree from which buds are to be worked, and immediately cut off the leaves at half the length of the petioles; make a transverse incision in the stock, and from the middle of this make a longitudinal one. A bud should next be removed from the shoot, by entering the knife about half an inch below the bud, more or less, according to the size of the stock and of the shoot; with a clean sloping cut, pass the knife upwards and inwards till under the bud, and then slope outwards so that the eye may be nearly in the middle of the piece or shield thus detached, or rather nearer its upper end. In doing this, the knife will necessarily cut off a portion of wood along with the bud, which is usually removed by the point of the knife and the edge of the thumb nail; see that in doing so the base of the bud is not also removed. If this came along with the wood, leaving a hole, the bud would probably be unsuccessful, and another should be taken off more shallow, so that the portion of wood to be removed may be very thin. If the wood comes out clean with the exception of a few slight woody fibers connected with the lower part of the base of the bud, these fibers need not be removed, for, in doing so, the tissue on the inner bark is very likely to be bruised. With the ivory handle of the budding-knife, raise the bark of the stock at each side of the incision, commencing at the corners immediately below the cross cuts. In raising the bark, the handle of the knife should never touch the portion of cambium lying on the alburnum, but, to avoid doing so, should be slipped along, pressing against the inner bark. In placing the bud, see that it is set directly where it is to grow; if it rubs up or down, the tissue will be bruised, and this will spoil the chance for success.

Inverted T-budding is the mode used in working a bud on a grape vine, as it is the returning sap that supplies the bud in this case, and this sap will not pass the cross cut. The writer has budded grapes successfully without making any cross cut, just open far enough lengthwise, spring the vine a little and the bud can be put in place and the sap will continue to flow all around it without interruption.

Inarching: This mode of propagation, which is also called grafting by approach, depends on the same principle as grafting, except that in this case both stock and scion are nourished by their own roots, while the union is taking place. Inarching was formerly employed for uniting two or more trees for picturesque effect, more than for the purpose of propagation. But inarching is now chiefly employed in propagating such exotic plants as cannot be readily propagated by other means. The writer has found it to be the best way of changing grape vines from one variety to another, and also the quickest way. It can be done in a case of this kind without losing one year's crop from the plant operated upon. Inarching is most successful when both plants are in full vigor of growth. In operating, place the plants in some convenient position so that the parts to be joined will come nicely together, tie them together just below the point where the union is to be, cut a strip of bark from two to six inches in length, according to the thickness of the stock. Then the inner bark of both should be brought straight together and tied quite firmly; in about three weeks the top of the stock may be slightly headed back to encourage the sap to flow to the scion. This heading back ought to be done a little at a time, and cleared off at pruning time when the plant is dormant.

The Specific Character of Precious Stones

In order to be properly designated as a precious stone a mineral must possess a certain number of definite properties which are rarely found associated in the same specimen. In the first place it must be transparent and perfectly limpid, in which case it is said to be of pure water. It must be bright and clear in color, that is quite unclouded. Furthermore, it must possess great brilliance or a "beautiful play of light;" these qualities directly depend on the optical characteristics of the mineral in question, and particularly on its refractive power and on what is called in optical physics its *dispersion*. As the term indicates this property consists in the ability to disperse the various rays of light, so that they exhibit all the colors of the spectrum on issuing from the gem. This latter property is possessed by the diamond in the highest degree. Finally, precious stones must be naturally hard, i. e. very resistant to friction; in this case they will preserve indefinitely their fire, their lustre, and their polish. The *density*[1] is of great importance in the determination and the classification of gems, because it is closely connected with their refractive power. Consequently, the majority of precious stones are very heavy in comparison with other transparent minerals and especially so with respect to imitations.

Another section of the model nursery

The more of these various qualities there are united in the same specimen and the more perfect the development of each, the more valuable the gem. There are, however, a few highly esteemed precious stones which are neither transparent, dense, very brilliant, nor vivid in color. Among these are the opal with its iridescent reflections, the turquoise whose delicate blue color furnishes a compensation for its opacity, and labradorite with its changeable tints. . . . In estimating the value of any stone furthermore, there are two other factors which must be considered namely, rarity and fashion. The greater or less abundance of any given gem upon the market is so closely connected with its price that at times the cost undergoes enormous fluctuations. The ruby affords a striking example of this, since at times its price equals or exceeds that of the diamond. During the last "diamond crisis," which occurred a few years ago, the price of diamonds fell so low as to utterly arrest business in this line for several months. The same sort of fluctuation in price frequently occurs through the whims of fashion; for example, the topaz, which was once highly valued, is today quite out of fashion. On the other hand, certain stones generally known as semi-precious stones have been much sought for of recent years because of the vogue of the jewelry produced by artistic craftsmanship; for instance, there are many beautiful kinds of quartz, jasper, agate and feldspar which, because of the variety of their tints and the diversity of brilliance and polish they are capable of in the hands of the engraver and the lapidary, lend themselves admirably to the production of artistic and tasteful jewels.

Samples of well-made grafts

The composition of precious stones is not a distinctive property although it is of great aid to the expert in testing them. It is also true that gems are of the most various composition. They include simple substances such as the diamond, which is pure carbon; various oxides, among which are to be classed the amethyst, the ruby and the sapphire; phosphates such as the turquoise, and above all silicates, among which may be mentioned the emerald, the topaz, rubellite or tourmaline.

Color is of no value as a test of precious stones since it is generally due to a sort of natural dyeing closely connected with the presence of impurities almost always present in such small quantities as to be indeterminable by analysis. These slight impurities frequently consist of oxides. Two points should be particularly emphasized: first, that stones of different composition, and correspondingly unequal in value, may be of the same color, and secondly, that the same species may exhibit very various tints. The first case is often met with in certain varieties of tourmaline (rubellite) of corundum (pink sapphire), rock crystal (rose quartz), triphane (kunzite), beryl (pink beryl or morganite), all of which are rose colored, so that the mere aspect of these stones *after cutting* is not sufficient to differentiate them. The second case is exhibited in extremely typical fashion in tourmaline, which offers almost the entire range of colors in the spectrum; among the various specimens of this stone some are quite colorless, and some are red, and the red shades include every tone, for example, pigeon's blood, similar to the most beautiful variety of rubies, purplish red and gradations of delicate pink; some specimens again are emerald green and others sapphire blue in color; others are brown like smoky quartz; and finally, still others have a pale yellow tone, lemon yellow or golden yellow. . . . It must be remembered also that the list of gems is increased from time to time by the addition of new varieties and even of entirely new species. This is true in the case of certain varieties of orthose. Lacroix called attention to the presence in Madagascar of certain specimens of this mineral which were perfectly clear and of a very beautiful golden yellow color. In the same way the spessartine garnet and certain varieties of the beryl need only to become better known in order to be ranked both by the public and by the jewelers among the most beautiful gems.

During the last few years, however, natural gems have had to compete with synthetic stones, also known as artificial or reconstituted gems. The art of the industrial world, preceded by the experiments of the laboratory, has succeeded in accomplishing the synthesis of a number of gems (ruby, sapphire, etc.) so economically as strongly to affect the commercial aspect of the jewelry trade. As a matter of fact synthetic stones resemble the natural ones in composition, hardness, color and brilliance. For this reason they cannot properly be called imitations. These latter possess merely the color and the transparency of real stones, being for the most part of mere scraps of glass skilfully cut, they do not support the test of time since they lack hardness; however, they have latterly been made with such a degree of perfection that in case of doubt it is advisable to consult an expert. . . .

The trade in gems, both cut and uncut, both mounted and unmounted, is enormous. Since 1871, when the diamond deposits of Africa were discovered, a billion dollars worth of these gems has been extracted from these mines. In New York City alone there are said to be more than $250,000,000 worth of cut gems, while the total value of the precious stones in France is about a billion dollars.

[1] See "Densivolumeter" in *La Rousse Menseul*, December 1918.

Recent Researches On Cholera*

How the Modern Physician Solved the Problem of Reducing Deaths from This Dread Disease

By Lieut.-Col. Sir Leonard Rogers, F.R.S.

THE subject I have chosen to speak about today is one regarding which probably but little is known outside the medical profession except that a great reduction in the death-rate has been brought about in recent years in perhaps the most justly dreaded disease of India, namely, cholera. I purpose to give you a brief account of my prolonged researches extending over more than a decade, and dealing with several distinct problems by means of a variety of methods of research, physiological, physical, and chemical, as I think this work will best illustrate the value of various collateral sciences in medical research.

The treatment of cholera at the beginning of the twentieth century remained much as it was seventy years before, when Latta and Mackintosh in Edinburgh in 1831 introduced the plan of injecting large quantities of normal saline solution into the veins to combat the collapse stage of cholera. This brilliant idea just failed to be a great discovery because no means were then found of retaining the fluid in the circulation, so that the apparently miraculous immediate effect of reviving the patient as one from the dead was usually followed by fatal recurrence of the terrible drain of fluid from the system. At the time I commenced my investigations the method was seldom used, as shown by the fact that a search through the records of the Calcutta European General Hospital from 1895 to 1904 showed no case in which large saline intravenous injections were given, while the mortality among ninety-five cases in those nine years reached the appalling figure of 87.4 per cent. Indeed, it was generally recognised that once a European patient reached the collapse stage in cholera recovery scarcely ever took place.

RECENT RESEARCHES ON THE TREATMENT OF CHOLERA.

As the first whole-time professor of pathology in Bengal, the home of cholera, who stuck to unlucrative research work for any length of time, this fell disease naturally attracted my attention, but it was not until after the completion of the first edition of my work on fevers in the tropics, the collection of material for which occupied me for twelve years, that I was able to take up serious work on cholera in 1908. I had previously made a number of blood-counts, and, with the help of my friend Major Megaw, had studied in 1906 Latta and Mackintosh's plan for injecting large amounts of normal or isotonic salt solutions—that is, one containing the same proportion of salts as the normal blood, controlling the quantities injected by special blood, and blood-pressure examinations—in the hope that, with the aid of these modern methods, better results would be obtained. This hope was largely disappointed, as the mortality only fell from 59 per cent. during the previous eleven years to 51.9 per cent. in 1906, and the method, which is a time-consuming one, was once more abandoned as of little service.

On thinking the matter over while on furlough, it occurred to me that on the physiological principle, that a high salt content tended to retain fluid in the blood, it would be worth while to try a stronger salt solution, and on return from leave with renewed energy at the end of 1907 I determined to put this theory to the test. Up to that time the strength of salines generally advised in cholera was 0.6 per cent., although recent physiological text-books have raised the figure for normal saline to 0.85 per cent. As I wished to give a hypertonic solution—that is, one containing more salt than the normal blood—I doubled the former strength and used a 1.2 per cent. of sodium chloride, or 120 grains to a pint, to which I afterwards added 4 grains of calcium chloride, because physiologists have found the latter salt to be beneficial to the heart. Capt. (now Lt.-Col.) Mackelvie very kindly carried out the hypertonic injections on the cases under his care, while I made a series of observations on the blood, to be related presently. The results may be summarised in a sentence by saying that by using two teaspoonfuls of common salt to a pint of water instead of one, the mortality from cholera was nearly halved. Nothing could well be simpler, yet nearly eighty years had elapsed since salines were first injected intravenously in cholera before the physiological principle of using a hypertonic instead of an isotonic solution was established. It was at once clear to me that a great advance had been made, which stimulated me to persevere with my investigations of the blood-changes in cholera, so as to place the whole subject on a firm scientific basis.

THE BLOOD CHANGES IN CHOLERA AS A BASIS FOR THE HYPERTONIC TREATMENT.

In the first place, I estimated the amount of chlorides in the blood before and after saline injections in a series of cases, and found that in the most severe cases they might even be below the normal point in spite of the great concentration of the blood, thus establishing a vicious circle and leading to further rapid loss of any isotonic solution injected into the veins. I further established that the hypertonic saline did materially raise the salt content of the blood, and to the greatest extent in recovering cases, which explained both the failure of the former isotonic and the success of the hypertonic solutions.

Another important point was to estimate the amount of fluid lost from the blood in cholera, so as to ascertain if the amount was in proportion to the severity of the case, and to learn how much salt solution it is necessary to inject to replace the loss. For this purpose I centrifuged a few drops of defibrinated blood obtained by pricking the finger-tip in a graduated capillary tube, and measured the volume of the solid corpuscles and of the fluid serum. By comparing the figures obtained with those of normal blood the percentage of fluid lost from the blood could be estimated. For example, in a severe case only 18 per cent. out of the original 55 per cent. of serum remained, showing a loss of no less than 67 per cent. of the fluid portion of the blood as a result of the copious evacuations. A series of such observations indicated that in mild cases of cholera not showing any serious collapse an average of 35 per cent. of the serum was lost; in collapse cases recovering after the hypertonic saline injections the loss averaged 52 per cent.; while in extremely severe cases, who were lost in spite of the new treatment, the figure averaged no less than 64 per cent., or almost two-thirds of the fluid of the blood. I have seen cases of cholera in which the blood was so thick that on opening a vein a drop of black blood slowly exuded having the consistency almost of tar—a condition which must rapidly terminate fatally if not quickly relieved. By repeating these estimations immediately after several pints of saline had been run rapidly into a vein in collapsed cholera cases, I was able to ascertain the quantities required to restore the normal fluidity of the blood, and found them, as I had suspected, to be much greater in severe cases than had formerly been given when isotonic solutions were in use. The hæmocrite, however, is too much of a laboratory instrument to be generally available, so a simple bedside method was needed. I therefore made use of Lloyd-Jones's method of estimating the specific gravity of the blood by means of a series of solutions of glycerine in water in small labelled bottles into which small drops of blood are gently blown from a capillary tube, and that in which one just floats is noted, which gives the required estimation. Whenever the pulse tends again to fail, the test is repeated as a guide to further treatment, and in several extremely severe cholera patients more than thirty pints of fluid have thus been injected in the course of several days with ultimate success in saving the lives of the patients.

PERMANGANATES AND OTHER DRUGS IN THE TREATMENT OF CHOLERA.

The success of the hypertonic saline injections in enabling the collapse stage of cholera largely to be overcome opened the way to a trial of drug treatment such as had never before been possible; for it is clear that unless the circulation can be restored and maintained, drugs given by the mouth will not even be absorbed, and can have no chance of exerting their beneficial action. Great care is required to make such tests trustworthy on account of the numerous sources of fallacy in estimating the effects of a given treatment. The best plan is to use a new drug in every other case in addition to the routine treatment, the remaining half of the cases then serving as a control. To take an example of this method of investigation, the late Sir Lauder Brunton some years ago advocated on physiological grounds the use of atropine in cholera, but was only able to try it in two mild cases with inconclusive results. I therefore gave the drug hypodermically in addition to the routine treatment in every other case of cholera in my wards for a whole year, with the result that the mortality was much lower in the atropine series, while a careful comparison of the two sets of cases as regards their severity showed them to be strictly comparable. I have, therefore, added atropine to my system of treatment with, I am sure, beneficial results. In a similar manner emetine was found to be useless in cholera.

Another point I wish to emphasize is the importance of carefully studying one's failures rather than being elated with any successes, as the further progress I have still to relate is mainly due to my adopting that practice. For the last ten years I have tabulated with the aid of shorthand—of the value of which in my work I cannot speak too highly—all the more important points of my cholera cases, now amounting to a little more than two thousand, and have closely studied the records of all fatal cases to ascertain the reasons for the failures with the view of finding means of lessening them. The following examples will illustrate some of the rseults thus obtained.

After an experience of a year and a half of the hypertonic treatment I realized that something more was required if the mortality was to be reduced still further. The failures appeared to me to be due largely to a recurrence of the collapse on account of absorption of the toxins produced by the cholera bacillus in the intestinal canal with the restoration of the circulation after the saline injections. Now the toxins are contained in the bodies of the innumerable bacilli, and set free when they break up, as they do in enormous numbers, for it has been shown that no fewer than 90 per cent. of comma bacilli die in culture-tubes within forty-eight hours. The use of intestinal antiseptics may very possibly add to the toxin absorption by killing the baccilli, which is, I believe, one of the reasons for their failure, as already stated. I therefore sought for some method of destroying the toxins themselves while still unabsorbed in the bowel: and, bearing in mind that they are largely albumoses and other unstable albuminous products of the metabolism of the organisms, and that such substances are readily destroyed or rendered inert by oxidisation, I experimented with various oxidising agents, and particularly with permanganates, which are well known to destroy rapidly *in vitro* the albumoses of snake venoms—a point at which I had previously worked. I was thus able to demonstrate that several times a lethal dose of dead comma bacilli containing the toxins could be neutralized by a small quantity of permanganates. A trial of large doses of permanganate of potash in pill form by the mouth, as much as one hundred grains sometimes being given in the course of several days, in addition to the hypertonic treatment, reduced the mortality of cholera during a year's use from 32.6 to 23.3 per cent., and it has now been used for more than nine years in my wards with increasingly favorable results. Permanganate pills have also been used in cholera epidemics in both the Bombay Presidency and the Central Provinces, in villages under conditions in which the saline treatment was not practicable, and favorable results have been reported, although, of course, it cannot by itself save the most severe cases with extreme collapse.

ALKALIS IN THE PREVENTION OF FATAL RENAL COMPLICATIONS.

There still remained one very important line of investigation, which has recently led to a further substantial reduction of the death-rate of cholera by enabling the common and most deadly suppression of the renal function largely to be averted. I know of nothing more disheartening than, after successfully maintaining the circulation by hypertonic salines through a life- and -death struggle for several days and nights, to be unable to get the kidneys to resume their functions, with ultimate loss of the patient. As the losses from collapse were steadily reduced by the various measures I have related, the death-rate from kidney failure continued much the same, and now became the most important remaining cause of loss of life, and it was apparent that some factor remained which was not clearly understood.

(*To be continued*)

*From the Presidential address to the Indian Science Congress, Bombay, 1919. Reprinted from *Nature* (London.)]

The Design of Artillery Ammunition

(*Concluded from page 27*)

pressure can, with a wide band, set up in the gun barrel a stress equal to that produced by the gases. The two forces, however, are not cumulative. The object of this driving band is twofold: to check the escape of gas and to rotate the projectile. So it must be designed to check the hot high-pressure gases, to withstand the initial longitudinal broaching force, and to withstand the twisting forces produced in accelerating the spin of the projectile. To do this, the band is set well back from the base and the seat is knurled deeply or given a waving thread.

DATA FOR DESIGN.

From the laws of interior ballistics, developed by very exhaustive research and experiments, it is now possible without much difficulty, if you are mathematically inclined, to plot the varying pressures and velocities in the bore of the gun with the travel of the projectile. From these pressure and velocity curves it is then a simple step to plot the acceleration curves both for linear and angular acceleration. From these two curves, since force is equal to mass times acceleration, it is possible to determine the forces acting at any point along the travel of the projectile. Then the problem of design of the parts of the projectile and fuse mechanism becomes one of ordinary machine design, for all the forces are now known.

The forces to be contended with are those of gas pressure, of linear and angular acceleration and of centrifugal force. Usually it is only necessary to know the maximum forces acting. Still, in certain fuse mechanisms it is not only necessary to know the total variation of forces acting in a gun but to know also the extreme variation in the various types of gun in which the mechanism may be fired. The maximum pressure and linear acceleration occur about at .8 of an expansion. In guns of constant twist rifling the angular acceleration reaches a maximum before the linear acceleration. In guns with parabolic twist rifling the angular acceleration reaches a maximum at the muzzle, where the linear acceleration is a minimum. It is, therefore, necessary in the case of any mechanical components allowed a relative rotation, to equate the friction moment due to line acceleration against the angular acceleration in order to find whether relative rotation will or will not take place as planned.

The accelerating forces vary from 25 pounds per grain of weight in the .30 caliber rifle to 2.3 pounds per grain in the 3-inch field gun and down to 1 pound per grain in the larger guns. There are 7,000 grains to a pound, which makes it obvious that the accelerating forces are tremendous. Naturally, any particular section of a projectile or fuse mechanism must be of sufficient area safely to withstand the load imposed by accelerating the mass in front of it. This gives a basis for the proper distribution of metal so far as strength is concerned. The centrifugal forces met with are also very high. The .30 caliber rifle bullet rotates at 150,000 revolutions per minute, the 15-pounder anti-aircraft shell at 25,000, the 3-inch field projectile at 17,000 and the larger caliber projectiles at 4,000.

The average requirements for shell steel are 65,000 pounds elastic limit and 85,000 ultimate tensile strength. Shrapnel specifications run higher to 95,000 pounds per square inch elastic limit and 120,000 pounds ultimate strength. It is the usual practice in both gun and projectile design to work the material literally to the limit. In compression, the stresses are usually not permitted to exceed the elastic limit; when they are permitted to do so, the possible deformation must be calculated. In tension, however, the elastic limit is never exceeded. The working stresses are ordinarily taken at 72 per cent. of the elastic limit of the material. An excess pressure of 12 per cent. is permissible in a gun when the situation requires the use of an extra charge, which will bring the stresses up to 80 per cent. of the elastic limit. In proving, an excess pressure of 25 per cent. is used, bringing the stresses to 90 per cent. of the elastic limit. It is never good engineering to take a chance, and therefore with such narrow limits imposed by necessity, the conditions and materials must be known to a nicety, and a most rigid inspection imposed. Projectiles and fuse mechanisms are used but once, but they must function that once and must not under any circumstances fail by premature action.

PREMATURES.

The accelerating forces are so great that, with the best designing, a premature detonation is liable to occur from the supersensitive condition of a primer or detonator. For this reason, a great deal of effort has been applied to the design of what are called "bore-safe" fuses, and several very effective fuses of this type have been developed. The Russian point-detonating fuse shown in Fig. 5 is one of the earlier ones of this type. A bore-safe fuse is one that cannot possibly detonate the shell while in the bore of the gun. A very great number of crews and guns have been destroyed in this war by premature detonations of the shell. A gun can be destroyed by a high-explosive shell even with a low-order detonation that has not originated from the fuse. This can be caused by the accelerating forces acting on a carelessly loaded charge or by ignition of the charge by the propelling gases through a faulty base plug or through seams or pipes in the forging. Shrapnel, however, with only a comparatively small black powder charge, cannot explode a gun, and it is quite common practice to set the shrapnel fuse to act while in the bore of the gun to produce what is called canister firing, which is fired point-blank into the advancing ranks of the enemy.

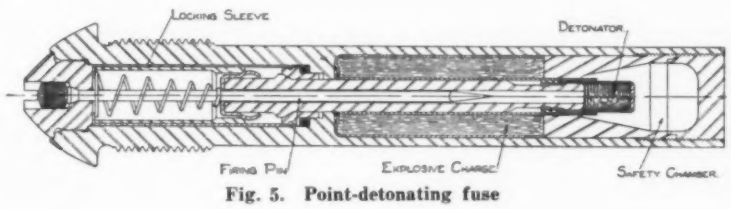


Fig. 5. Point-detonating fuse

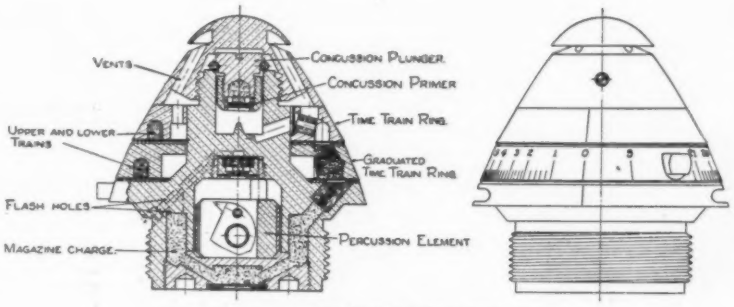


Fig. 6. Combination time-fuse

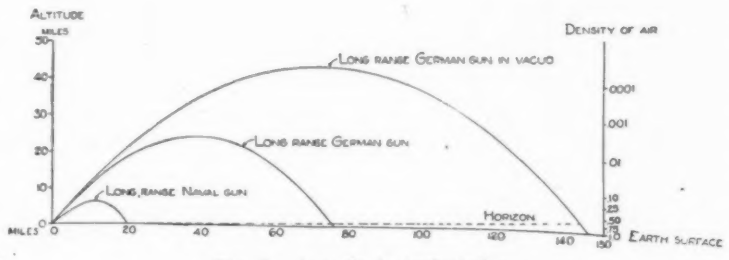


Fig. 7. A study in trajectories

TYPE OF SHELL.

There are two main types of shell, shrapnel and high explosive. Shrapnel uses a time fuse set to burst above the enemy at such a point that the cone of dispersion of the ejected balls will scatter to about one ball per square yard. A 3-inch shrapnel contains 270 balls one-half inch in diameter. These are spread out over a front of about 50 feet wide, the shrapnel bursting from 50 to 100 yards of the ground, varying with the angle of the fall. The high-explosive shells use both time and impact fuses. This is the first war in which high-explosive shells have been used to any great extent and their destruction is tremendous. Their effectiveness is obtained both from the concussion and fragmentation, principally the latter. The profuse use of gas shells in this war was even more of an innovation. These shells are similar in construction to high-explosive shells, with the exception that a small bursting charge is used in conjunction with a container whose character depends upon the gas composition.

Although the stresses due to acceleration in the gun are high, the stresses due to retardation on impact are even higher, and in armor-piercing work can run up to ten times the value of the former. Armor-piercing projectiles are made of best quality chrome nickel steel and carefully heat treated to give a hard point, with the temper drawn gradually towards the base. The point is protected by a soft steel cap; the object of this cap is to support the point until it has penetrated sufficiently to be able to withstand the load of the projectile; for if the entire energy of the projectile were localized on the point at the start it would be hopelessly crushed. As it is, the point, being supported on all sides by metal, comes through without injury. This soft steel cap increases the penetrating power of the shot by about 30 per cent.; it also increases its bite on inclined impact. The large caliber guns can pierce the heaviest armor at battle ranges of over ten miles.

FUSES.

Time fuses are intended to burst in air and are used against troops and aircraft. Impact fuses are used against troops for ground work and for armor piercing. Direct-action or sensitive-point fuses are used against troops, and as they burst on the surface of the ground, create the greatest havoc. The action of these fuses requires the retardation of the striker or firing pin only. The marvellous effectiveness of the French 75-mm. guns at the beginning of the war was due to this type of fuse, which was later utilized by the other belligerents. The indirect-impact fuses, depending upon the principle of the inertia plunger, will enter the ground several feet before acting, as their action requires the retardation of the entire shell. When a further delay element is added, they are used for demolition work. Such fuses are also used for armor-piercing projectiles. For armor piercing the fuse must necessarily be placed in the base of the shell. For ordinary field work the fuse is usually placed at the point of the shell, as this makes a much simpler manufacturing proposition.

An impact fuse contains simply the firing-pin mechanism and a combination of primer-detonator and booster, the purpose of which is to build up from a comparatively feeble mechanical blow a brusque explosion sufficient to detonate the bursting charge with high order. This is illustrated in Fig. 5. The locking sleeve is released by the "set back" from the shock of propulsion, so that on impact the detonator, normally in the safety chamber, is free to move forward opposite the explosive charge and to drive ahead against the firing-pin and initiate the explosion.

A time fuse has an additional fuse element consisting of an adjustable slow-burning time train which regulates the fuse action independently of impact. These time-train rings are loaded with black meal powder and are pressed up at 68,000 pounds per square inch. They are carefully vented to give regularity in burning. If the venting is insufficient, the burning is too fast or even short-circuited. If the venting is too liberal, the burning is too slow or may even go out. The reason is that black powder burns very feebly in a partial vacuum and will hardly burn at all in a complete vaccum. Therefore, the angle of fire especially for high angles, has a great influence on the time of fuse action and must be allowed for. A time fuse is illustrated in Fig. 6. The shock of propulsion sets back the concussion plunger and fires the primer, igniting the powder time train. When the upper and lower trains are burnt through, the magazine charge of the fuse is ignited, which in turn ignites the bursting charge of the shell. The time of burning is regulated by shifting the relative position of the flash holes and powder trains, which is done by turning the graduated lower ring. A percussion element is usually added to function on impact in case of failure in the time element. A number of promising mechanical time fuses have been developed, but they have not as yet reached the reliability of the powder train fuse.

For demolishing ground work a constant delay-action fuse is satisfactory, which allows the shell to enter the

creases its bite on inclined impact. The large caliber guns can pierce the heaviest armor at battle ranges of over ten miles.

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ground and explode like a mine. For destroying a battleship, however, an auto-selective delay action is desirable; a fuse that will function on the smoke-stack or rigging of a ship or on striking heavy armor plate will automatically delay action until penetrated. Such a fuse has been developed. For airplane and balloon fighting a fuse is required that will burst on contact with cloth, and such fuses have also been developed.

TRACERS.

In aircraft fighting it is obviously necessary, when impact fuses are used, that the shell be so arranged as to destroy itself before returning to earth if the target is missed. This can be done either by means of the fuse or by means of a tracer loaded with illuminating mixture. In designing these tracers it must be kept in mind that the hot gases both in the gun and in the blast present a strongly reducing atmosphere. A tracer is attached to the base of the shell, giving a bright streak of light by which the flight of the projectile can be followed. This tracer is so arranged that after burning a given number of seconds, which is sufficient to reach its goal, it will burn through and destroy the shell by igniting the charge, if the fuse has not previously acted on the target. Such tracers without the self-destroying feature have been used very extensively in all sizes of ammunition to check up the trajectory over hilltops and also to check up the point of impact. In machine-gun fire tracer bullets are used every fifth round or oftener, so the operator can direct the gun pretty much as he would a garden hose.

FLIGHT OF PROJECTILES.

If a projectile were fired in a vacuum the only force acting upon it would be that of gravity and the path would be a parabola. The maximum range would be obtained at an angle of elevation of 45° and the altitude attained by the shot at this elevation would be one-quarter of the range. However, the resistance of the atmosphere very greatly complicates the problem. It changes the angles of departure and impact, shortens the range and produces a side drift. Firing in the atmosphere gives a maximum range at about 33° elevation of the gun.

The tendency of a projectile fired from a gun is to keep its axis at the angle of departure. However, the action of gravity soon brings this axis at an angle with the line of flight and the resistance of the atmosphere acts at a point below the apex of the shell. The gyroscopic forces then turn the point of the shell to the right, if the rifling is right-handed. This then brings the atmosphere resistance on the left of the shell point and the gyroscopic forces turn the point downward. This constant struggle between the inertia of the projectile, the gyroscopic forces, the resistances of the atmosphere and the action of gravity keeps the point of the shell fairly tangent to the trajectory and makes it strike point on. In order to utilize this gyroscopic action it is necessary that the line of air resistance must intersect the axis in front of the center of gravity of the shell. In a solid shot this would require that the altitude of the cone of the point be equal to or greater than one-half the radius of the projectile.

ATMOSPHERIC RESISTANCE.

The resistance of the atmosphere is on the mean quadratic; that is, it varies with the square of the velocity. More truly, however, it varies from this by a law symmetrical with respect to the velocity of sound in air. It varies with the density of the air, with the temperature, with the moisture present, and with the form of the projectile; for an ogival head having a generating curve concave toward the axis, the resistance varies directly with the sine of the mean tangent, or inversely with the area of the surface. The standard ogive is one having a radius of two calibers. If we call its resistance 1, that for a spherical head will be 2, that for a flat end 4, and that for an ogival head of eight-caliber radius will be ½. The resistance can also be reduced by altering the form of the base, and boat-tail projectiles are coming more into use. This cannot be carried very far, however, without affecting the stability of the projectile's flight. Some 12 per cent. reduction in resistance can be obtained by boat-tail projectiles.

The resistance to rotation is, of course, not great; it is entirely skin friction. A three-inch shell, for example, rotating at 16,000 revolutions per minute, will lose about 3,000 revolutions per minute in an 8,000-yard range.

GERMAN LONG-RANGE GUNS.

A brief description of some of the characteristics of the German long-range guns will bring out somewhat more clearly the points taken up. The projectile has a long ogival windshield of ten-caliber radius to reduce the atmospheric resistance to a minimum. Its trajectory is shown in Fig. 7. The muzzle velocity is 5,000 feet per second, the highest velocity ever used in practice, though it had been attained experimentally some thirty years ago. The velocity at the apex is 2,300 feet per second and the striking velocity, reaccelerated by the action of gravity, is 3,000 feet per second. This is several times the velocity of sound in the atmosphere, so the approach of such a projectile would be unheralded by sound. The side drift amounts to .8 of a mile. The curvature of the earth adds half a mile to the range. Same .4 of a mile was also added to the range by the rotation of the earth due to the direction of fire, in bombarding Paris from St. Gobain. The time of flight for this 76-mile range is practically three minutes. And a very interesting point is that the average flight of the projectile is in a 28½-inch vacuum.

PHOTOGRAPHS OF PROJECTILES IN FLIGHT.

When photographs are taken of small-arms projectiles in flight, the influence of the point of the projectile is very clearly brought out. The shadows of the passing projectiles and their accompanying atmospheric waves are thrown into the camera by a powerful light from a concave mirror or lens. The light and the time of exposure are obtained from an electric spark, and demonstrates a very remarkable speed for chemical action on a sensitized film. This method of photographing can be applied to all classes of physical as well as ballistic processes. High-frequency vibrations are generated by means of a damped spark gap and vibratory circuit in connection with a direct-current circuit which serve to produce the electric sparks used. When a series of pictures is taken of a bullet in flight at 2,700 feet per second, the film is passed through the camera at the rate of 1,350 feet per second, and the electric sparks are produced at the rate of 92,000 per second.

Pictures of this sort always show the characteristic bow wave, which forms the basis of the principle of the supersensitive balloon fuse. In flight the striker of this fuse floats on the bow wave. There is absolutely nothing else that keeps it off the primer. The instant that an obstruction, no matter how light, is encountered, the wave disappears and the striker jams back on the primer, exploding the shell. These fuses will explode on your silk handkerchief, not to mention balloon and airplane fabrics.

Radiometallography

(*Concluded from page* 19)

dovetails: after which the seam upon the outside may be welded. Automatic instruments are being developed for accomplishing this welding without skilled welding labor and at great speed.

The system of casting employed is applicable to other purposes than ships. Cast steel drydocks are possible with a considerable saving in weight.

Castings in the United States for locomotive tender frames, vestibule ends of cars, trucks, etc., are rapidly displacing built up riveted forms with profit to the users and added safety to the traveling public. The cast steel ship enterprise is aimed at a similar development for marine transportation.

Upon compliance with the specifications of the Cast Steel Ship Corporation for castings and joints, Lloyd's Register of Shipping has signified in writing their readiness to classify cast steel ships. The Technical Department of the United States Shipping Board, Emergency Fleet Corporation, has also approved our plans for a cast steel welded ship.

The company is arranging contracts at the present time for a few hulls of ships and intends to license enough American shipways and provide casting resources therefor to care for normal needs under conditions that should give the lead to American shipping. —MYRON F. HILL in *The Iron Age* (New York).

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